

NASA Technical Memorandum 88348

**Some Innovations and
Accomplishments of
Ames Research Center
Since Its Inception**

Ames Research Center Staff

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ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

Some Innovations and Accomplishments of Ames Research Center Since Its Inception

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Moffett Field, California



National Aeronautics
and Space Administration

Scientific and Technical
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FOREWORD

Earlier this year (1986) at the request of Dr. James C. Fletcher, NASA Administrator, Ames Research Center produced a preliminary document describing its innovations and accomplishments since its inception in 1940. Since then the document has been reviewed, edited, extended, and illustrated to produce this publication for the record.

Publication of a document of this type is subject to a number of possible pitfalls. Someone must decide which innovations and accomplishments are worthy of inclusion. Since this choice is a purely subjective one and since it will change with time, the selection is bound to disappoint some researchers who think their work should have been included. Also, other researchers or organizations may think their contributions to any of the included items may have been slighted or overlooked. Accordingly, only a very few individuals have been mentioned in the publication. In any case, for a number of the individual items it is not possible to identify the responsible individual.

It is almost inevitable that this publication will tend to emphasize recent innovations and accomplishments which appear important at this time. Items dating back to the 1940s or 1950s, for instance, may not appear to be important now because of the progress of technology. Also, many have probably been forgotten in the march of time.

It should be pointed out that a number of accomplishments of Ames-Dryden Flight Research Facility were started before that Facility became part of Ames Research Center. Such accomplishments include the first supersonic flight, the first hypersonic flight, the lunar landing research vehicle, and the first digital fly-by-wire aircraft.

With these reservations, we have nevertheless decided to publish this account of the innovations and accomplishments of Ames Research Center.

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INTRODUCTION

The purpose of this document is to present a listing and brief description of what Ames Research Center considers its outstanding innovations and accomplishments since the Center was established in 1940. Section A describes, not necessarily in priority order, 12 innovations which we consider very important. Section B lists, in random order, 10 accomplishments which, although not purely innovative in character, are nevertheless very important for other reasons. Section C lists an additional 36 innovations/accomplishments which cover a broad spectrum of our Center's other engineering and scientific work. These are listed under the categories of astronautics and aeronautics.

The following 12 innovative items are judged to be very important:

1. Development of computational fluid dynamics and large scientific computer systems
2. Blunt-body reentry concept
3. Modeling the universe
4. First digital fly-by-wire aircraft
5. Lifting-body reentry vehicle
6. Computational chemistry
7. First oblique-wing research aircraft (AD-1)
8. Tilt-rotor research aircraft
9. Supersonic area rule
10. Airborne and space infrared observatories
11. Thermal protection systems for Space Shuttle Orbiter
12. Building blocks of life

Many of the accomplishments of Ames Research Center, not purely innovative in character, are now listed, not necessarily in order of importance.

1. First supersonic flight
2. First hypersonic flight
3. Pioneer Space Probes
4. Pioneer Venus
5. Arc-jet wind tunnel development
6. Outstanding flight-research simulators
7. Outstanding flight-research capability
8. High-air-speed test facilities
9. World's largest wind tunnel
10. First jet STOL transport aircraft-augmentor wing

In addition to the very important innovations and accomplishments already discussed, other significant innovations and accomplishments are listed under *aeronautics* and under *astronautics*. The items included under *astronautics* are

1. Tektites and ablation
2. Design studies of aeroassisted orbital transfer vehicles
3. Structure of unknown planetary atmospheres
4. Ablating heat-shield design
5. Advanced spaceborne information-management systems

6. Lunar magnetic observatories
7. Bone-stiffness analyzer
8. Vestibular research facility
9. Lunar-landing research vehicle
10. Viking-Lander biology experiment
11. Ames space suit developments
12. Ames lunar science
13. Search for extraterrestrial intelligence

The items listed under *aeronautics* are

1. Digital electronic engine controls
2. Helicopter design codes
3. Fuel-efficiency flight-profile algorithms
4. Free-tip rotor
5. Quiet, short-haul research aircraft
6. X-wing, rotor-systems research aircraft
7. Aerodynamic design utilizing numerical optimization
8. HIMAT, remotely piloted research aircraft for high-maneuverability research
9. World-standard aircraft-parameter-estimation technology
10. Fault-tolerant software
11. Major advance in hidden-line algorithm
12. Flight-test-maneuver autopilot concept
13. Remotely augmented vehicle test concept
14. Composite aeroelastic tailoring for transonic maneuvering
15. Unpowered landing-approach technology
16. Fighter agility study
17. Transition-cone flight experiment
18. Laser speckle velocimetry
19. Conical camber
20. Aircraft fire safety; improved seats
21. Rotating-cylinder-flap research aircraft
22. Invention and development of variable-stability airplane
23. Anti-ice protection for aircraft
24. A portable, tactical-approach-guidance system
25. Development of thrust reversers for jet aircraft
26. Flight studies of boundary-layer control (BLC) to improve low-speed aircraft performance
27. General aviation synthesis program computer code
28. Aviation safety reporting system
29. Man-Vehicle Systems Research Facility
30. Line-oriented flight training
31. Cockpit resource management
32. Workload prediction model
33. Aircraft automation
34. Supersonic-transport certification criteria
35. V/STOL handling qualities
36. Cooper-Harper rating of aircraft handling qualities

A. DESCRIPTION OF IMPORTANT INNOVATIONS OF AMES RESEARCH CENTER

1. DEVELOPMENT OF COMPUTATIONAL FLUID DYNAMICS AND LARGE SCIENTIFIC COMPUTING SYSTEMS

Description

Ames Research Center has been responsible for a major innovation in aerospace technology: the development and advancement of computational fluid dynamics (CFD) as a discipline, and its utilization by the aerospace community as both a design and an analysis tool. Computing programs have been developed that solve the nonlinear equations of fluid mechanics that model the basic fluid physics mechanisms inherent in flows of aerodynamic interest. Graphics analysis and visualization hardware and software have been developed that allow ready access and visualization of extremely large and complex data solutions generated by the new computing systems.

In addition, Ames has been the leader in the development of large scientific computing systems, culminating in the conception and development of the Numerical Aerodynamic Simulation (NAS) program (fig. 1). From the early, relatively small, single-processor computers to the present large, multiprocessor computing systems, Ames has led the specification and utilization of these major new tools for aerospace systems. It pioneered parallel computation for fluid mechanics with ILLIAC IV.

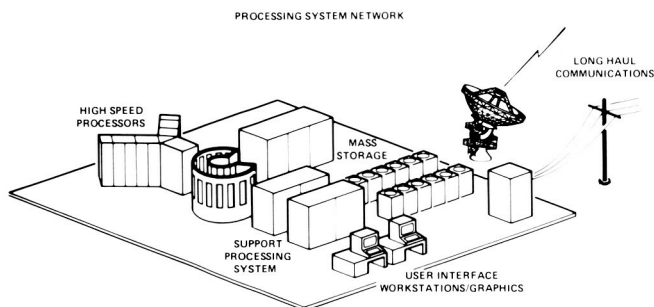


Figure 1. Numerical Aerodynamic Simulation

Significance

The significance of these developments lies in the changes that have been made within the aerospace community in general and within the aerospace industry in particular. The general nature of fluid dynamics research has been permanently changed, in that the computer is now an integral part of that process, for both basic and applied research problems. This new capability has enabled fundamental mechanisms of

turbulence to be determined and the accurate simulation of the flow fields about very complex aerospace vehicle configurations to be accomplished. The design process has been fundamentally altered to include the large computer system, with the overall result that new vehicles are more accurately simulated and thousands of hours of wind tunnel test time are saved in the process.

2. BLUNT-BODY REENTRY CONCEPT

Description

Ballistic entry into Earth's atmosphere from circular satellite orbits and from lunar return trajectories was a formidable problem in the early part of the decade of the 1950s. Considerable controversy about a "thermal barrier" led many to think that atmospheric flight under those conditions might not be feasible. Careful study of the equations of motion of hypervelocity flight in the Earth's atmosphere was done at Ames by H. J. Allen (fig. 2), A. J. Eggers, and D. R. Chapman. Some reasonable simplifications of the equations of motion by Allen and Eggers made parametric studies possible wherein vehicle mass and size, entry velocity, and entry angle could be varied systematically. Importantly, aerodynamic heating predictions were coupled to the simplified trajectory equations. H. J. Allen was able to show that for almost any Earth entry condition, convective heating would be minimized by a blunt configuration. Atmospheric air would be raised quickly to a high temperature as it crossed the bow shock wave, and would sweep around the body rapidly so that most of the energy associated with friction heating would be left behind in a very hot wake. Very little of that heat would be accepted aboard the blunt-nosed vehicle. Thus the important blunt-body concept was born.

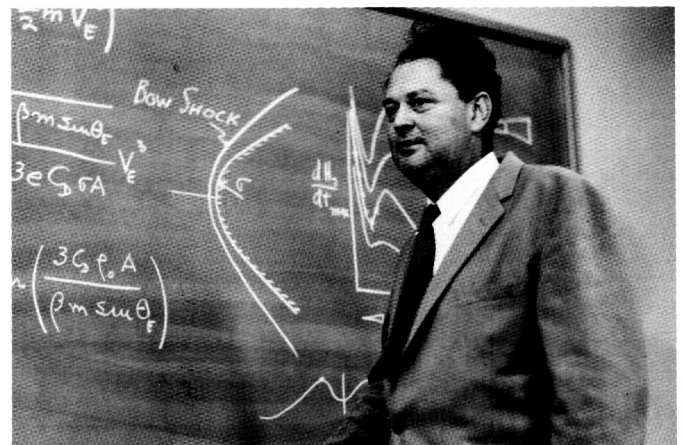


Figure 2. H. J. Allen and Blunt-Body Reentry Concept

Significance

The concept has had very useful consequences: It led to the configuration of the Gemini orbital entry body, the Apollo configuration for the round trip to the Moon, the lifting-entry body concept, and more recently, nose and wing leading-edge shapes for the Space Shuttle. The concept has been useful for entry into other planetary atmospheres as well. Moreover, the concept of a blunt body to reduce convective heating rates has not only solved the thermal barrier problem, but has led to the development of new thermal protection systems and materials that have played a major role in entry-vehicle technology. Ames Research Center has played a leading role in material technology development, partly as a result of the blunt-body concept.

The blunt-body concept has had a major influence on the design of nearly all entry vehicles. It also greatly influenced the Space Shuttle entry. During the early phase of the Shuttle entry, the Shuttle is kept at a very high angle of attack — thus presenting a blunt face to the oncoming air. After it passes through the period of high heating, the angle of attack is reduced so it can fly as an airplane.

3. MODELING THE UNIVERSE

Description

Ames scientists have pioneered the use of supercomputers to investigate the behavior of large astrophysical systems in which self-gravity is important, such as galaxies, protostellar clouds, and the solar nebula. The evolutions of these systems are governed by complex collective phenomena that, like turbulence, defy conventional analysis. Thus numerical experiments have been designed to identify and quantify the primary physical processes. Three-dimensional n -body calculations that follow the motions of more than 10^5 stars in their own gravitational field have been used to explore the dynamical evolution of galaxies. The first calculations of the collapse of rotating interstellar clouds were performed at Ames; these employed advanced moving-grid techniques that permitted accurate results over a dynamic range of nearly 10 orders of magnitude in density. Current projects include the application of advanced hydrodynamic numerical codes for the first direct calculation of the properties of turbulent gas in systems dominated by rotational and gravitational forces, calculations that will be crucial for the understanding of the primitive solar nebula from which the planets formed.

Other scientific modeling efforts at Ames have provided fundamental knowledge regarding the nature of the planets and their atmospheres, origins, and evolution. A hierarchy of computer codes of varying complexity have been developed

to understand the radiative-dynamical effects that drive climatic variability in the atmospheres of the planets. Calculations using these codes have demonstrated the importance of aerosol loading of atmospheres in such contexts as global dust storms (on Mars), volcanic activity, asteroidal or cometary impact, and nuclear explosions. Modeling of the thermal evolutions of solid planets led to the prediction, verified by spectacular spacecraft images, that Jupiter's moon Io is volcanically active. Detailed modeling of spiral density and bending waves in Saturn's rings permitted Ames scientists and their collaborators to make the first unequivocal identification of these waves.

Significance

Numerical computations of large, self-gravitating systems have provided insights into their fundamental behavior that were unobtainable by other means, either by direct observations or by conventional analysis. It was demonstrated that the true shape of elliptical galaxies is likely to be prolate, rather than oblate, as previously assumed. These highly evolved galaxies are of controversial origin, and therefore there is great interest in their morphology and internal dynamics. The Ames numerical experiments have also demonstrated that collisions among galaxies result in much greater thermalization of their stellar components than previously assumed; that is, collective effects cause the collisions to be extremely "inelastic," in spite of the fact that the stars themselves do not actually collide. The pioneering work on protostellar collapse begun at Ames has formed the basis of a large body of astrophysical theory regarding the nature of star formation, currently being pursued (among others) by Ames's Center for Star Formation, a consortium involving Ames and two University of California astronomy departments, and funded by NASA Headquarters.

Ames accomplishments in the theory of solar system origin and evolution have established the Center as a key institution in the nation's space exploration program. The research on climatic variability has had profound impacts on subjects ranging from the predicted terrestrial climate, to theories of the extinction of the dinosaurs, to the environmental effects of nuclear war — in some cases stimulating entirely new branches of applied atmospheric research. Prediction of the thermal state of the remote celestial body Io, besides providing a large impetus for the previously untested discipline of comparative planetology, established tidal dissipation as an important, but previously unrecognized, source of planetary internal energy. The work on ring dynamics has laid the foundation for the use of current observations of planetary ring systems to explore the physics of the preplanetary environment, when large numbers of orbiting, interacting particles comprised the solar system.

4. FIRST DIGITAL FLY-BY-WIRE AIRCRAFT

Description

The world's first digital fly-by-wire (DFBW) aircraft flight-control system was developed and demonstrated on the NASA F-8 aircraft (fig. 3), with the mechanical controls removed prior to first flight in 1972. A subsequent phase developed the first fault-tolerant, multichannel, DFBW system.

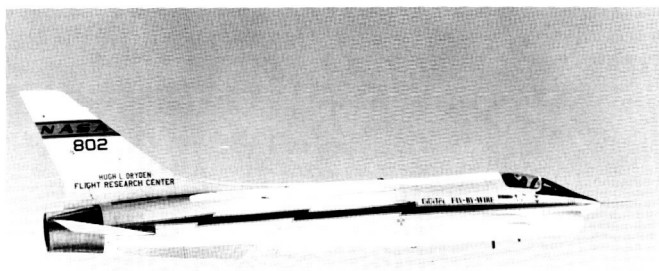


Figure 3. F-8 Digital Fly-by-Wire Aircraft In Flight

Significance

This program demonstrated the feasibility of pure DFBW technology and provided hardware and software methodology for system designers. This technology allowed large increases in system capability because many nonlinear functions can be incorporated to maximize performance throughout the flight envelope without increasing the hardware complexity or reducing system reliability. It also allows automatic self-checking of the system to provide the high integrity necessary for assured flight safety. The F-8 DFBW system was the forerunner of the Shuttle flight-control system as well.

5. LIFTING-BODY REENTRY VEHICLE

Description

Lifting bodies were designed to allow reentry from space in a more controlled manner than is feasible with a ballistic entry. Shedding conventional wings, the lifting body (fig. 4) provided a high volumetric efficiency without the protection needed for wings. The blunt-nose shape conceived at Ames was flown first in 1963 to prove that the concept could be flown to a landing in a more or less conventional manner.

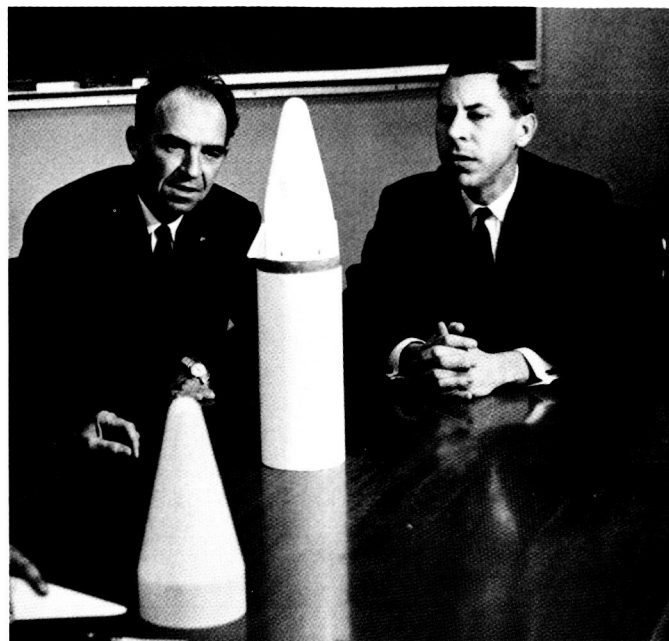


Figure 4. Lifting-Body Reentry Vehicle

Significance

The lifting-body program demonstrated the practicality of the lifting-body entry concept and gave NASA the confidence to choose a lifting-body entry configuration rather than a ballistic configuration for the Space Shuttle.

6. COMPUTATIONAL CHEMISTRY

Description

Ames has taken the discipline of computational chemistry, which was primarily of academic interest (and the results of which were accurate only for single atoms), and led the development of this field to the point where today molecular properties, chemical reaction rates, gas-solid interactions, and properties of materials can be predicted. The results of computational chemistry for two or more atoms, which 20 years ago were ignored by experimentalists, are now actively sought by them to design, interpret, and verify their tests. Whereas previous calculations were valid only for single atoms, present methods are being used to accurately simulate gas/surface interactions involving 30 atoms and to predict interatomic forces in clusters as large as 65 atoms. In addition, the forces from these calculations are being used in the simulation of material properties containing up to 10,000 interacting atoms.

Significance

Computational chemistry has, for example, played a major role in the design of the Galileo heat shield. Radiative cross sections and absorption coefficients derived for numerous species were used to predict the forebody and afterbody radiative heating in the flow surrounding the probe. Computational chemistry is currently being used to predict the impact of nonequilibrium effects on aeroassisted orbital transfer vehicles (AOTV), to analyze and design improved polymer materials resistant to atomic oxygen degradation, and to investigate catalytic and noncatalytic processes to design improved noncatalytic thermal protection systems. However, while great progress has been made, the major impact of computational chemistry has yet to be realized because it has the potential to enable us to understand and design new, stronger, lightweight materials for aerospace use and improved catalysts for substantially increased fuel efficiency.

7. FIRST OBLIQUE-WING RESEARCH AIRCRAFT (AD-1)

Description

The oblique-wing concept (fig. 5) conceived by R. T. Jones at Ames-Moffett was brought along from its infancy to flying status through the use of wind tunnel testing and

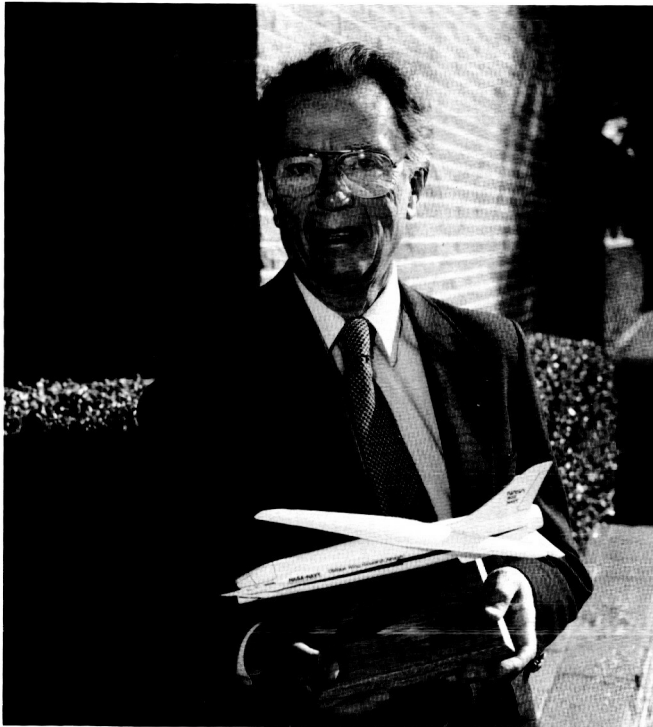


Figure 5. R. T. Jones with Oblique-Wing Model

computer modeling. To obtain a flight assessment, a low-cost approach was taken utilizing sailplane fabrication technology. The low-speed, manned airplane assessed flight-based handling qualities, validated stability and control, and verified the concept.

Significance

This program gave a critical boost in credibility and visibility to a very promising concept. Because the approach was very low cost, time and effort could be directed almost immediately to evaluating the concept in flight. Because of the excellent results, the Navy has joined with NASA to sponsor a transonic, manned, research airplane version and sees the concept as a highly attractive option for meeting long-term Navy needs.

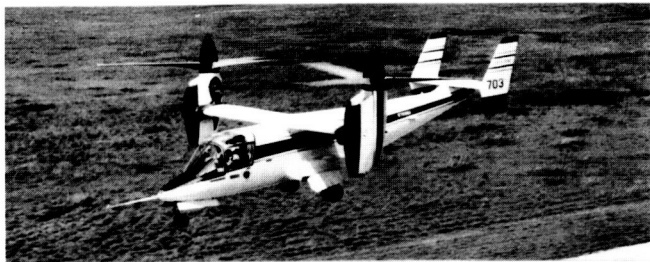
8. TILT-ROTOR RESEARCH AIRCRAFT

Description

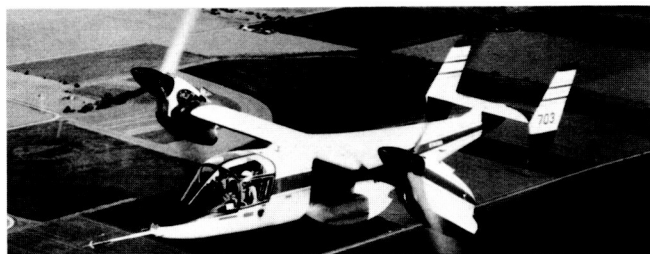
The feasibility of a convertiplane, i.e., an aircraft that can fly as a helicopter and convert the rotors to the propeller position as in a turboprop, was first flight-tested successfully in the 1950s with the XV-3. This aircraft demonstrated the feasibility of the idea, but it was severely underpowered, was limited in speed and payload, and revealed a potentially catastrophic whirl-mode instability problem. During the 1960s, NASA, Army, and industry engineers addressed these problems through analyses and small- and large-scale wind tunnel investigations. Confident that the problems had been solved, Ames and the Army began the XV-15 program in 1972 to develop two tilt-prop-rotor research aircraft (fig. 6) capable of demonstrating in flight the viability of the concept for entry into the military and civil transportation systems. These aircraft were successfully developed as minimum-cost vehicles using as many off-the-shelf components as practical, and successfully met the goal of demonstrating an aircraft free of instabilities and capable of achieving 300 knots airspeed with enough maneuvering envelope for the military to evaluate it for existing mission suitability.

Significance

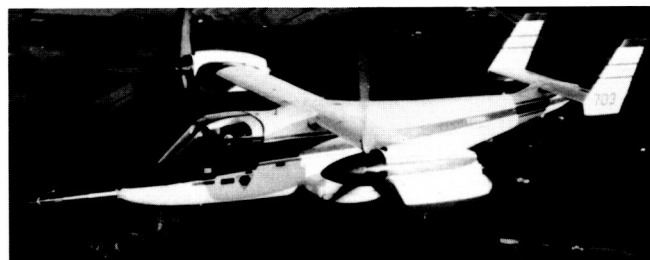
For the first time, the nation has a truly viable aircraft that can take off and land vertically, hover efficiently, and cruise at speeds of about 300 knots. In addition to high speed, the tilt-rotor concept offers advantages with respect to fuel economy, noise, and vibration. Ames researchers are currently working toward a 400-knot tilt rotor as an achievable second-generation machine for this exciting concept.



VERTICAL TAKEOFF



TRANSITION



HORIZONTAL FLIGHT

Figure 6. XV-15 Tilt-Rotor Aircraft

The really special significance of the project to NASA is that it has been accepted by the military for application directly to an operational aircraft development program — the V-22 Osprey — for initial use by the Marines and subsequent production for the Army and Air Force as well.

Furthermore, an FAA/NASA/DOD-sponsored study is currently under way to assess the broader implications of the V-22 aircraft development to the nation, and includes potential for other versions and sizes, civil development issues, etc. The New York Port Authority is also sponsoring a study of tilt-rotor technology as a potential solution to air-transportation problems in the New York area.

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9. SUPERSONIC AREA RULE

Description

In the 1951-52 time frame, the important discovery was made by Richard Whitcomb of Langley Research Center that by indenting the fuselage of an airplane in the region of the wing attachments the drag of an airplane near the speed of sound could be significantly reduced. The indented body was popularly known as the Marilyn Monroe body and the principle was known as the transonic area rule. While this development did reduce the drag slightly above and below sonic speeds, it did not minimize the drag at supersonic Mach numbers well above unity, where drag is usually higher than at sonic speed. A few years later, Dr. R. T. Jones discovered the supersonic area rule, which permitted minimizing the drag of airplanes at speeds well above the speed of sound. This rule is based on controlling the cross-sectional areas of the airplane cut out by Mach cones rather than by simple cross-sectional areas as used in the transonic area rule.

Significance

The supersonic area rule provides a design means whereby the drag of an airplane at a given supersonic speed can be minimized. The large savings in drag possible using the rule is of great importance for increasing the range of supersonic airplanes. It is readily applicable to a complete airplane, including any external stores or fuel tanks.

10. AIRBORNE AND SPACE INFRARED OBSERVATORIES

Description

Most of the important information about the chemical composition and physical conditions associated with remote planets, satellites, cool stars, and regions of star formation is obtained from their IR radiation. Such radiation is largely obscured from ground-based observers by water in the Earth's atmosphere. Consequently, Ames, in collaboration with university astronomers, has developed facilities for flying telescopes open-port (no IR-absorbing windows) in high-altitude aircraft to get above most of the atmospheric water. The airborne nature of the observatories makes them highly transportable so that they are also useful for events that are observable only at remote locations (e.g., eclipses, occultations). This feature makes the telescopes useful over a wide range of wavelengths from ultraviolet to millimeter

waves. The first open-port telescope developed was a gyro-stabilized, 30-cm-diameter reflector mounted in a Lear Jet and flown up to 50,000 ft. This experiment was followed by the Kuiper Airborne Observatory (KAO), a 91-cm-diameter reflector flown on a modified C-141 aircraft up to 45,000 ft. The KAO accommodates many different kinds of instruments (fig. 7) and serves a large community of scientists with typically 80 research flights per year.

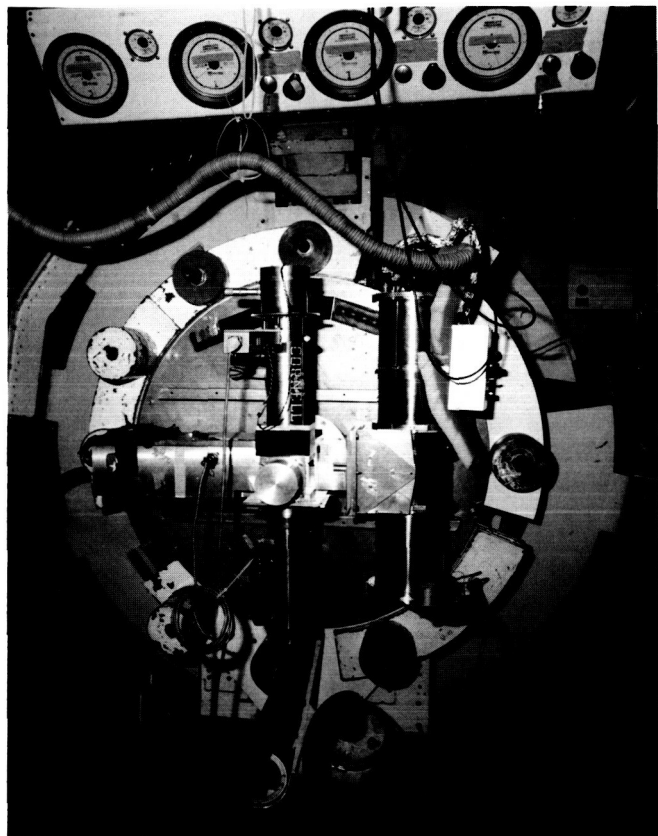


Figure 7. KAO Telescope in C-141 Aircraft

While airborne observatories largely overcome the problem of atmospheric absorption of IR light, the foreground emission of the Earth's atmosphere and the telescope optics themselves seriously limited the sensitivity of the instruments. An enormous improvement was achieved with the Infrared Astronomy Satellite (IRAS) telescope (fig. 8) that was developed at Ames in collaboration with the Jet Propulsion Laboratory (JPL), the Netherlands, and the United Kingdom. IRAS has a 60-cm-diameter mirror and an array of detectors cooled to near absolute zero by superfluid helium. The highly successful operation of IRAS has been followed by further technological developments in handling liquid helium in zero gravity and in more sensitive IR-array detectors.

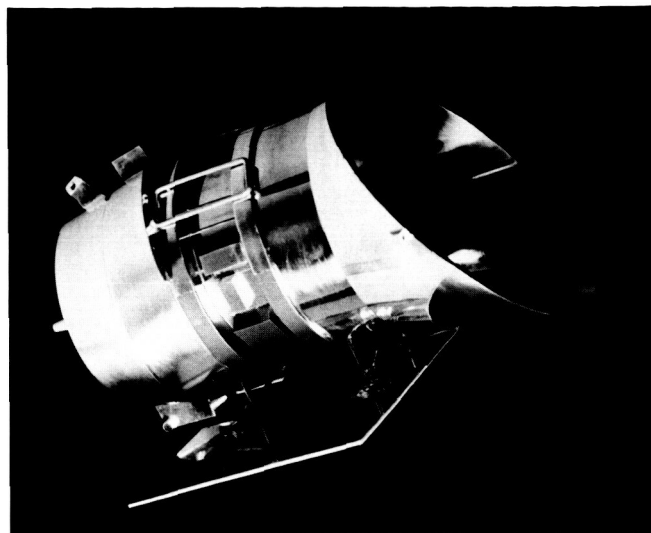


Figure 8. IRAS Telescope

Significance

The 30-cm-diameter Lear Jet telescope pioneered the study of astronomy in the 30- to 300- μ m wavelength range. Among its achievements are the discovery of internal heat sources in Jupiter and Saturn and sulfuric acid in the clouds of Venus. The KAO achievements include the discovery of the rings of Uranus, detection of unexpectedly large sources of IR energy in spiral galaxies, identification of water vapor in Comet Halley, measurements of IR luminosities of the outer planets, and the discovery of 63 atomic, molecular, and solid-state spectral features in the interstellar medium.

IRAS mapped the entire celestial sphere in four IR bands for 8 to 120 μ m, presenting astronomers with an entirely new picture of the Universe. Over 250,000 new IR sources were found. Although the data analysis is by no means finished, many new phenomena have drawn interest, including structure in the zodiacal cloud (suggestive of recent asteroid collisions), particle rings around some stars, and cool, wispy filaments (the IR cirrus) covering much of the sky seen from space.

11. THERMAL PROTECTION SYSTEMS FOR THE SPACE SHUTTLE ORBITER

The Space Shuttle Orbiter is the world's first reusable atmospheric entry vehicle. A key requirement for its success is the use of a reusable thermal protection system (TPS). Ames was instrumental in the development of the reusable surface insulation (RSI) TPS used on the Shuttle Orbiters.

Ames invented the black borosilicate glass coating called reaction-cured glass (RCG) which covers two-thirds of the

Orbiter surface. This glass coating provided a thermally stable, high-emittance surface for the silica tiles and made it possible to manufacture tiles to the demanding tolerances required. A more refractory and stronger silica reusable surface insulation (LI-2200) also was developed, which replaced 10% of the baseline (LI-900) tile system on Columbia when a critical tile-strength problem was encountered. A new class of tile material called fibrous refractory composite insulation (FRCI-12) was invented, which replaced about 10% of the earlier tiles (LI-2200 and LI-900), providing both a more durable and a lower-weight (1000-lb savings) system.

A flexible silica blanket insulation, called advanced, flexible, reusable surface insulation (AFRSI), was developed with Johns Manville that replaced most of the white, low-temperature, reusable-surface insulation (LRSI) on the last two Orbiters, Atlantis and Discovery. This material, which covers most of the top surface of each Orbiter, is cheaper, lighter, and more easily maintained than the LRSI it replaced.

Hot-gas flow between tiles during atmospheric entry was considered a serious problem during orbiter development (fig. 9). Ames developed a gap filler, which consisted of a ceramic cloth impregnated with a silicone polymer, that was adopted as a temporary solution to the gap heating problem for Columbia. The "Ames Gap Filler" was so successful that it was adopted as a permanent solution for gap-flow problems on all the Orbiters. More than 10,000 are now used on each vehicle.



Figure 9. Thermal Test of Space Shuttle Tiles
in Arc-Jet Wind Tunnel

Ames played a major role in developing and testing the external insulation materials and design concepts for the Space Shuttle Orbiter using the Ames arc-jet complex. These concepts were a total break with the past tradition of ablative, nonreusable heat shields used on previous entry vehicles. The thermal protection system for the Space Shuttle Orbiter has turned out to be lighter than originally expected and to have a lower refurbishment rate than planned. Ames innovations have contributed significantly to this performance. The families of materials that have evolved from this work are candidates for heat-shielding future vehicles such as the Aerobraking Orbital Transfer Vehicle and the Aerospace Plane.

12. BUILDING BLOCKS OF LIFE

Description

Special combinations of analytical techniques, including gas chromatograph and mass spectrometry, were developed to detect and characterize minute amounts of organic compounds in extraterrestrial materials. The use of these methods of analysis in the study of geological samples has become one of the most fruitful scientific approaches used to elucidate the natural origins of living systems and their building blocks.

Significance

Ames scientists unambiguously detected the presence of complex organic molecules of extraterrestrial origin in the Murcheson carbonaceous meteorite (fig. 10). This work provided the first indisputable evidence of prebiotic chemical evolution by detecting a mixture of amino acids, one type of the "building blocks of life." These amino acids were shown to be achiral (lacking "handedness") as would be expected from a nonbiological origin, in contrast to the chiral amino acids ("left-handed") produced by living systems. In addition, the organic compounds were found to be composed of carbon with a ratio of isotopes, $^{13}\text{C}/^{12}\text{C}$, that fell far outside the range exhibited by organic matter on Earth.

Application of the same techniques to the study of lunar samples for evidence of chemical evolution indicated that complex organic compounds were not indigenous to the Moon and that the chemistry of the biogenic elements (hydrogen, carbon, and nitrogen) in these samples resulted largely from injection of the corresponding charged ions from the solar wind into the surfaces of lunar soil grains. Analogous processes are now thought to contribute to the chemistry of the surfaces of interstellar dust grains, asteroids, and planetary satellites that lack atmospheres.

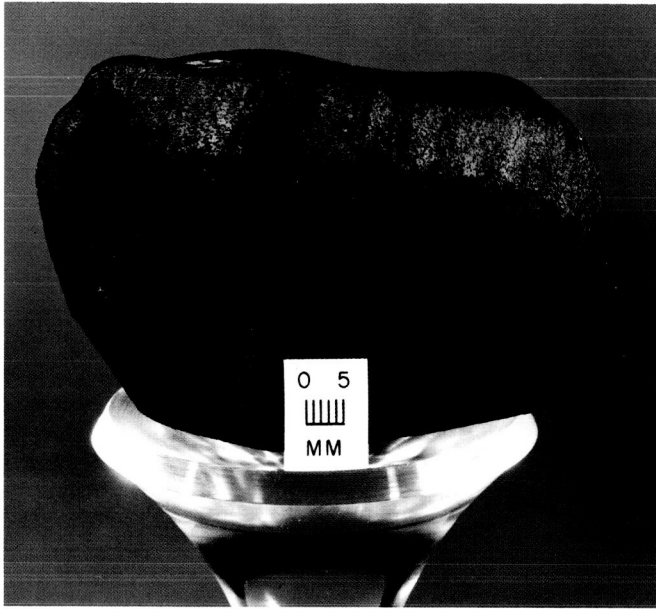


Figure 10. The Murchison Meteorite

Additional research on the organic compounds in the Murchison meteorite has provided evidence for their origin in processes that occurred on the parent body of the meteorite rather than in the gas and dust regime of the solar nebula; these processes, analogous to volcanic outgassing and weathering on Earth, also produced clays. Apparently, the parent bodies of carbonaceous meteorites, formed as planetoids very early in the solar system, underwent processes that are expected to have occurred on the early Earth; their study now holds promise of providing insight into the nature of the environment and the processes that took place in the analogous prebiotic period of Earth history from which no geological samples of this planet have survived (fig. 11).

Studies of the interaction of organic matter with clays, in turn, have led to the discovery that they can acquire and store energy from the environment as well as catalyze the linking of amino acids to each other. These discoveries serve as the basis for the theory that energy stored in minerals could have been crucial in driving the chemical reactions necessary on the primitive Earth for the assembly of biological building blocks into the prebiotic precursors of proteins and nucleic acids.



Figure 11. Artist's Conception of Evolution of Life

B. DESCRIPTION OF IMPORTANT ACCOMPLISHMENTS OF AMES RESEARCH CENTER

In the following accomplishments the element of innovation is usually present; however, the accomplishments are frequently the results of the combined efforts of a number of people or organizations, and it is not always easy to recognize the significant contributions of all the participants.

1. FIRST SUPERSONIC FLIGHT

The first level flight beyond the speed of sound was made in October 1947 by Air Force Captain Charles Yeager in the Bell XS-1 airplane (fig. 12). The XS-1 was the first in a series of rocket-powered research aircraft designed and built to explore the sound "barrier" and flight in the supersonic regime beyond. The program was jointly conducted by the National Advisory Committee for Aeronautics, the Air Force, and the Navy. The first flight to actually exceed Mach 1 proved once and for all that there was no physical "wall" that would preclude flight at or beyond this point. The research and exploration conducted during the remainder of the program proceeded to open up the entire supersonic regime for flight by both military and civilian aircraft throughout the world.



Figure 12. The Airplane That Broke the Speed of Sound

2. FIRST HYPERSONIC FLIGHT

Although there is no definite point at which flight is considered hypersonic, convention normally assigns this designation to flight at or above a Mach number of 5. The first flight of a manned aircraft into this regime was conducted in June 1961 in the X-15 aircraft (fig. 13). The X-15 was designed to extend flight research from the low supersonic area already being investigated to the high supersonic and hypersonic regimes out to a Mach number of 6.

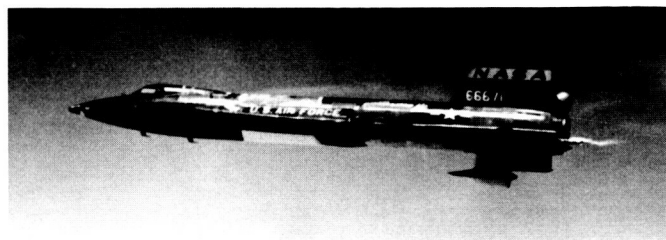


Figure 13. The First Airplane to Fly at Hypersonic Speed the X-15

Laboratory results on structures, heating, and aerodynamics were extended to actual flight by the X-15 program. Analytical and theoretical prediction techniques were formulated, modified, and updated based on the data provided by the X-15. These results, reaching to the near-space environment, were used to provide the confidence and design for the space program of the United States.

3. PIONEER SPACE PROBES

Pioneers 6-9

Pioneers 6-9 were the first spacecraft to systematically explore the solar environment outside the Earth's immediate influences, near (0.8 to 1.2 times) Earth's orbital radius. Beginning in 1965, these probes (fig. 14) explored interplanetary space measuring magnetic fields, cosmic rays, high-energy particles, electron density, electric fields, and cosmic dust. Pioneers 6 and 7 continue to be productive when contacted in 1986 - 21 and 20 years, respectively, since their launches into space.

Pioneers 10 and 11

Two modest and reliable spacecraft, designed as the first objects to explore the solar system beyond the orbit of Mars, were launched in 1972 and 1973. Their specific objective was to determine whether the asteroid belt could be safely penetrated, to examine the harsh radiation environment near Jupiter, and to reconnoiter as far as practical into deep space.

These spacecraft are spin-stabilized for simplicity, are powered with radioisotope thermoelectric generators for independence from the Sun, and are uniquely free of magnetic fields for sensitivity to interplanetary measurements. Instruments from universities, industry, and NASA laboratories measured interplanetary particulate density, solar wind characteristics, cosmic rays, and volumes of data on Jupiter.

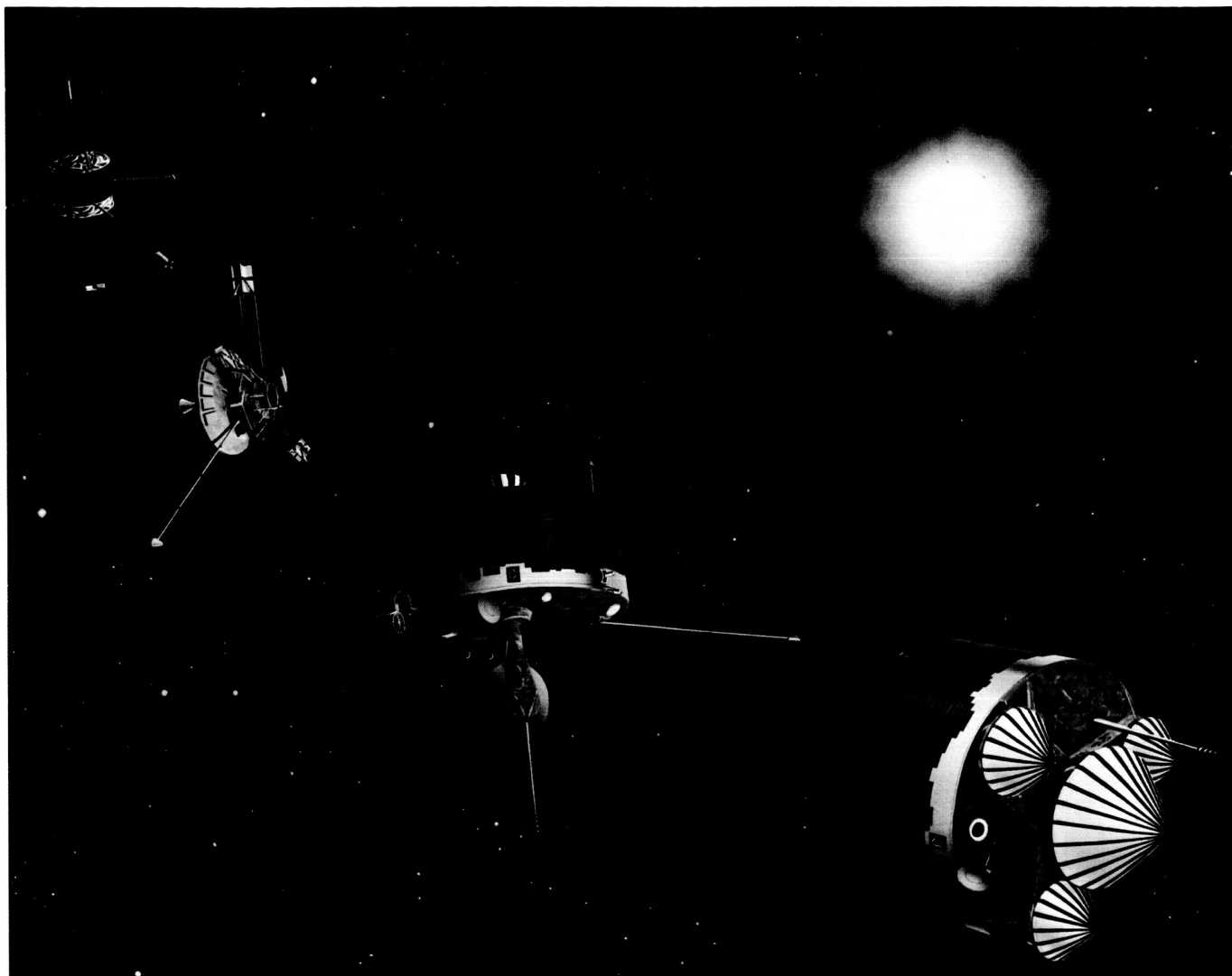


Figure 14. Pioneer Space Probes

Saturn, too, was first examined in 1979 by Pioneer 11 after Pioneer 10's success at Jupiter permitted this added goal. Pioneers 10 and 11 continue exploration in 1986 at 39 and 21 times the Earth's distance from the Sun. Pioneer 10 is escaping the solar system about opposite the general directions of Pioneer 11 and Voyager, and will continue to be our most distant space probe for its remaining life.

Pioneers 10 and 11 proved the practicality of flight beyond Mars, defined in unsurpassed detail the magnetic and radiation environments surrounding Jupiter and Saturn, and opened an entirely new perspective on the vastness and activity of the Sun's influence in space. They continue, in 1986, to provide data on the variations caused by solar activity at remote distances, and Pioneer 10 suggests the possibility of penetrating beyond the heliosphere into the interstellar medium within the next few years.

4. PIONEER VENUS

The concept of using entry probes of known aerodynamic characteristics to determine critical parameters for the determination of the structure of planetary atmospheres was developed at Ames. Two spacecraft were developed to orbit and probe the atmosphere of Venus (fig. 15). Revolutionary new findings on the anomalous abundance of volatiles and a cold nightside thermosphere of Venus were obtained from this mission. These probes have been used to gather knowledge of the Martian and Venusian atmospheres and will be going to Jupiter with the coming Galileo mission.

The techniques developed for these probes have become a basic part of the science of the determination of planetary atmospheres.

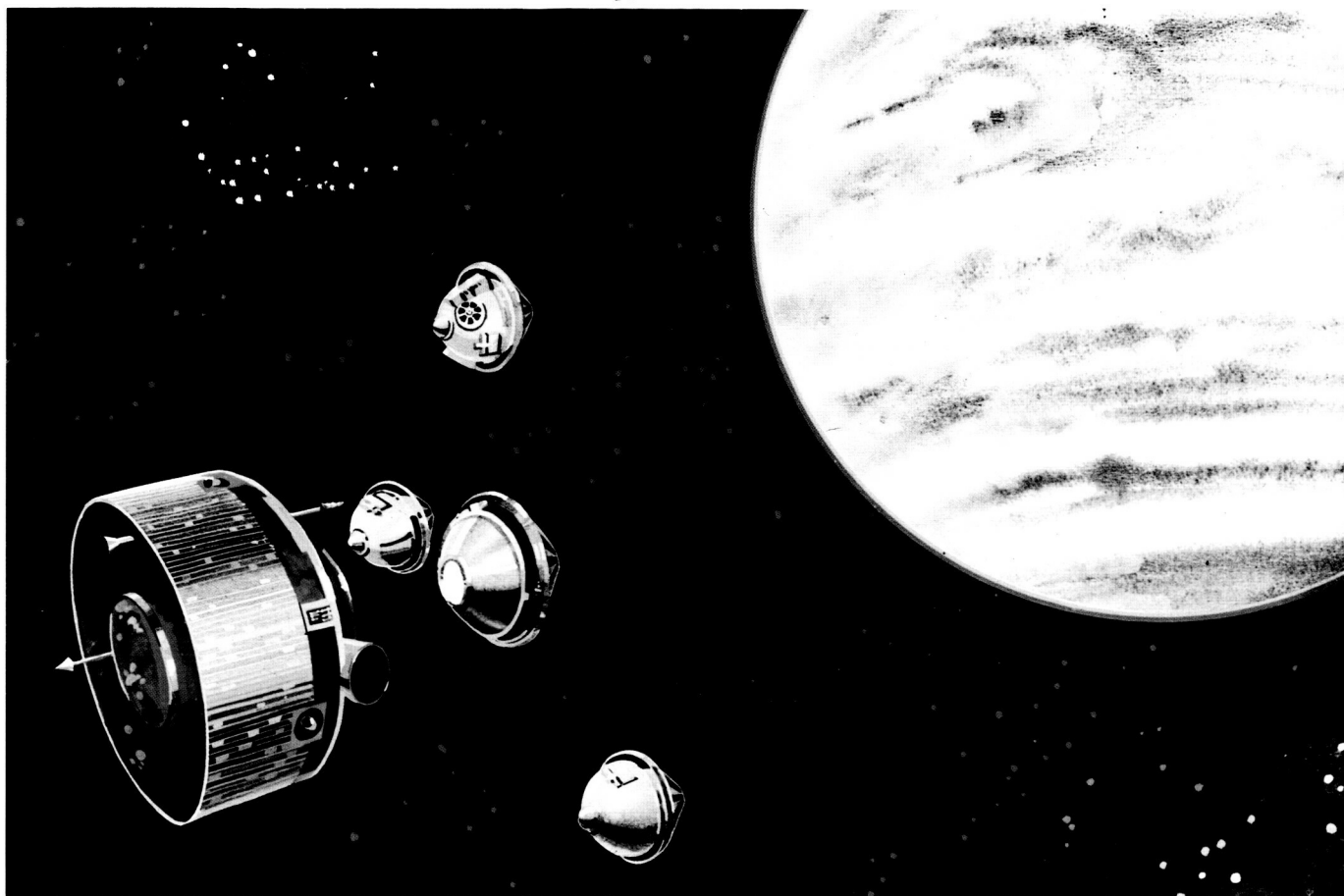


Figure 15. Pioneer Venus

5. ARC-JET WIND TUNNEL DEVELOPMENT

The technology associated with spaceflight required that ground-based facilities be developed that are capable of simulating high-temperature flows occurring during planetary entry. The arc-jet wind tunnel is the device which filled this requirement.

Theoretical and developmental work at Ames paved the way for the arc-jet wind tunnels (fig. 16), which provide high-temperature plasma flows that simulate entry conditions over a wide range of conditions. The flows are continuous; 30-min run times, for example, were employed during tests of the Shuttle Orbiter thermal tiles. The high power capability of the arc heater for these wind tunnels allows for large-scale testing as well. Full-scale elements for the Shuttle Orbiter were tested in the arc-jet wind tunnels at Ames. The high power capability allows for real-gas flow simulation over a wide range of entry conditions for Earth as well as for conditions for entering other planets' "atmospheres."

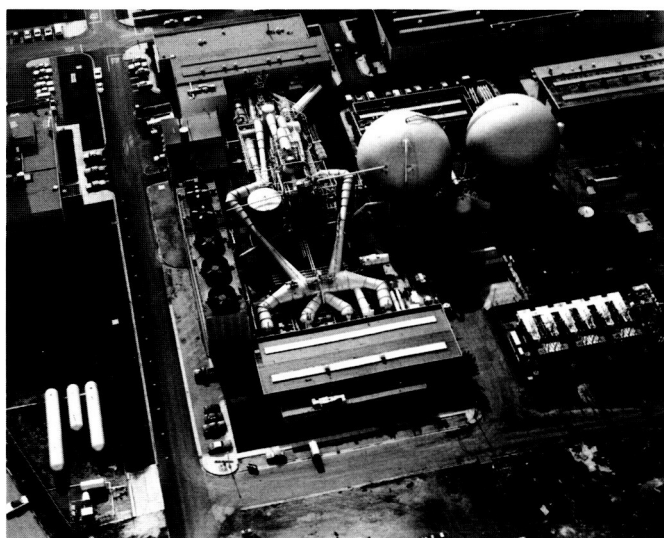


Figure 16. Arc-Jet Wind Tunnel Complex

6. OUTSTANDING FLIGHT-RESEARCH SIMULATORS

Ames has what is probably the world's premier flight-research-simulation complex. This simulation capability includes fixed-base chairs, fixed-base simulators, and motion simulators. The earliest motion simulator, constructed in 1958, was a two-degree-of-freedom (pitch and roll) electrically driven chair. Shortly after this, a five-degree-of-freedom motion simulator was constructed at the end of a 30-ft radius. Although better than the chair, the five-degree-of-freedom simulator had limitations on range, rates, and accuracy of motion. There was a continuous growth in simulation capability during the ensuing decades. Digital control and advanced optical systems were incorporated. The entire process of simulator progression supported the nation's flight-research programs, including V/STOL aircraft and rotorcraft.

The newest and most prominent of the simulators are the Vertical Motion Simulators (VMS) (fig. 17), and the Man-Vehicle Systems Research Facility (MVSRF) (fig. 18). Supporting these various facilities is a visual imagery system or a computer-generated imagery system.

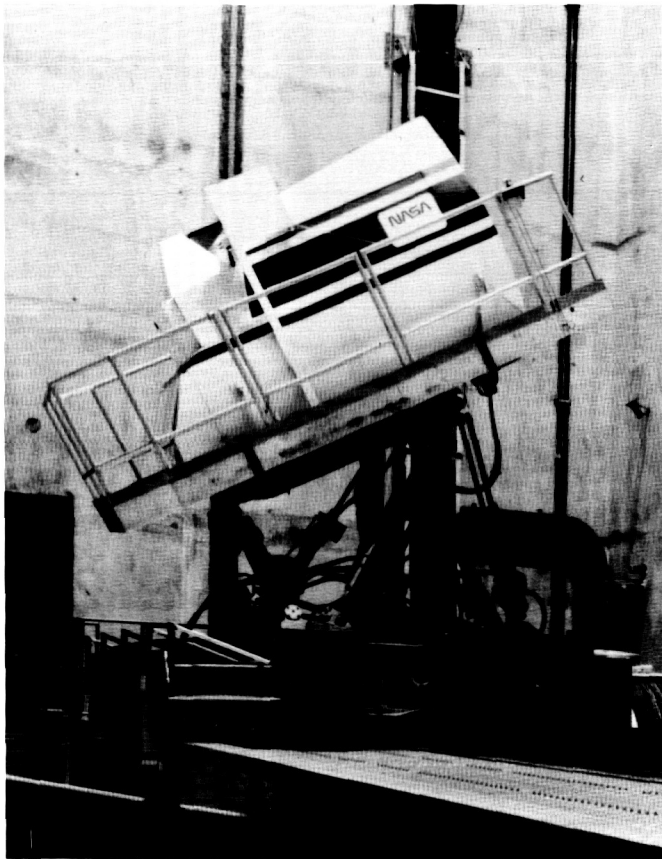


Figure 17. Vertical Motion Simulator



Figure 18. Man-Vehicle System Research Facility,
Advanced Cockpit

These facilities have contributed to a variety of research experiments as well as national needs, including

- Airworthiness and certification criteria for civil transports
- Concept development for the Department of Defense (DOD)
- Handling qualities and flight dynamics research for rotorcraft and powered-lift vehicles
- Aircraft systems development for DOD
- Space Shuttle research in controls systems, landing-system evaluations, and remote-site landing evaluations
- Accident-investigation research involving wind shear and jet upset problems

7. OUTSTANDING FLIGHT-RESEARCH CAPABILITY

An outstanding high-performance flight-research and aeronautical test capability is centered at the Ames-Dryden Flight Research Facility (fig. 19). The facility, located at Edwards, California, is on the edge of Rogers Lake, a vast, hard-packed, dry lakebed in the Mojave Desert of southern California. Rogers Lake, in combination with the adjoining Rosamond Lake, provides a level, 65-square-mile landing area. Its remote location and relative isolation from airways and population centers, coupled with extraordinary flying weather of exceptional visibility and year-round sunny skies,



Figure 19. Ames-Dryden Flight Test Facility

provides an environmentally superb testing area unmatched in the world.

The Dryden facility and associated remote installations reflect the latest in state-of-the-art technology and application of advanced test techniques and procedures. Central to these facilities is the NASA Western Aeronautical Test Range that provides the tracking, telemetry, communications, and real-time processing and display systems for the mission support of unique and high-performance aerospace vehicles.

Another key and unique capability at the Ames-Dryden complex is the Flight Simulation/Remotely Piloted Research Vehicle (RPRV) Facility. This facility is the most sophisticated test and control capability dedicated to RPRV aircraft and flight vehicles within the United States.

The Flight Loads Research Facility provides the ability to test structural components and complete vehicles under the combined effects of loads and elevated temperatures, and to calibrate and evaluate flight instrumentation under expected conditions of flight.

This aeronautical test capability has historically supported the achievement of challenging national aeronautical goals, beginning with the first manned flight faster than the speed of sound in the X-1, through the first suborbital flights of the X-15, to modern-day uniquely configured aircraft such as the forward-swept-wing X-29 and the Space Shuttle.

8. HIGH-AIRSPEED TEST FACILITIES

Starting in about 1949, NASA Ames embarked on a long and exciting program to develop a series of aerodynamic test-

ing facilities of progressively increasing speed of the air relative to the model. These facilities were needed to conduct aerodynamic testing related to hypersonic aircraft and missiles, ICBMs, and reentry vehicles.

- The first *supersonic free-flight facility*, the idea of Harvey Allen, was completed in 1949. In order to increase the airspeed relative to the model, the model was fired upstream into a supersonic airstream. This concept was improved upon in a series of innovative developments.
- To increase the launch speed of the model, a *light-gas gun* was developed by Alex Charters in the early 1950s. In this gun a piston in a tube was driven by an explosion to compress gas in a tube until the pressure broke a diaphragm at the entrance of a launching tube and accelerated the model to high speed before it left the muzzle. The facility, completed in 1957, could develop muzzle velocities of about 13,000 ft/sec.
- The next major development in light-gas-gun technology was to replace the steel piston by a shock wave, initiated by an explosive charge, to compress the driver gas. This development eliminated the worrisome problem of mechanical impact associated with the steel piston.
- By utilizing a two-stage, shock-driver, light-gas gun, muzzle velocities of over 20,000 ft/sec were achieved. By using this gun and a shock tunnel having an airspeed of 15,000 ft/sec, relative velocities between the air and model approaching 40,000 ft/sec were achieved. The facility was called the *hypersonic free-flight facility* (fig. 20).

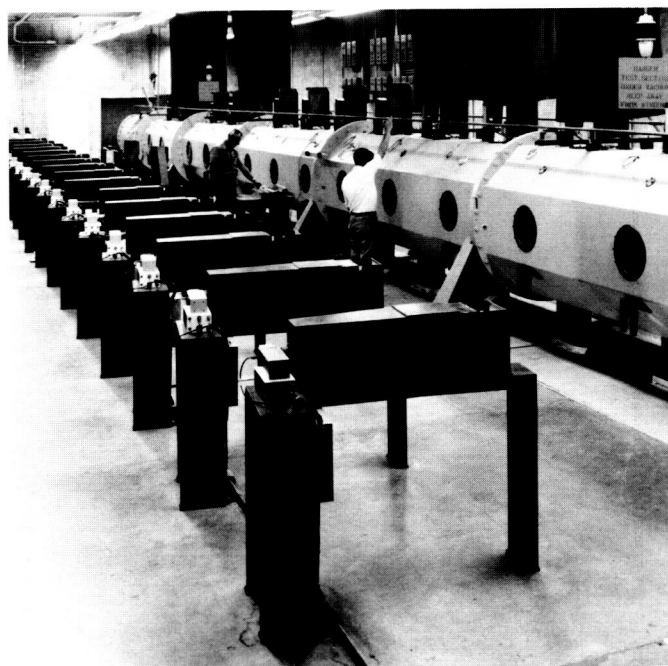


Figure 20. Hypersonic Free-Flight Facility

- The next increment in increasing airspeed was achieved by going back to a piston driver, but the piston was a deformable plastic one. A taper near the end of the driver tube caught the piston and increased the compression ratio. By 1965, relative velocities of about 50,000 ft/sec were achieved.

Firings were made into a pressure vessel which could vary in pressure from 0.01 atmosphere to 10 atmospheres, thus allowing a great variation in Reynolds numbers. The facility is called the *pressurized ballistic range*.

Tests were conducted in these facilities of every vehicle used in the manned space effort, from Mercury through Gemini through Apollo. Much valuable aerodynamic data were collected that helped in the design of these vehicles. Conditions could be achieved that could not be reached in any other ground-based facility.

These facilities are still operational and have contributed to many other programs, including the planetary missions Viking (Mars), Pioneer (Venus), and Galileo (Jupiter). Currently they are being used for tests of various designs for Orbital Transfer Vehicles.

9. WORLD'S LARGEST WIND TUNNEL

The world's largest wind tunnel complex, the National Full-Scale Aerodynamics Complex (NFAC) (fig. 21) is located at Ames-Moffett. The NFAC includes the Outdoor Aerodynamic Research Facility (OARF), the 40- by 80-Foot Wind Tunnel and the 80- by 120-Foot Wind Tunnel (fig. 22). This unique complex provides the capability of performing wind tunnel testing on aerospace vehicles and components at full and large scale.



Figure 21. National Full-Scale Aerodynamics Complex

The OARF is used to check out models or aircraft before they are installed in the 40- by 80 or 80- by 120 wind tunnel, to obtain zero wind force and moment data for VTOL models/aircraft, to obtain exhaust gas reingestion results for VTOL hardware, and to obtain near- and far-field acoustic data for propulsion systems and advanced rotorcraft.

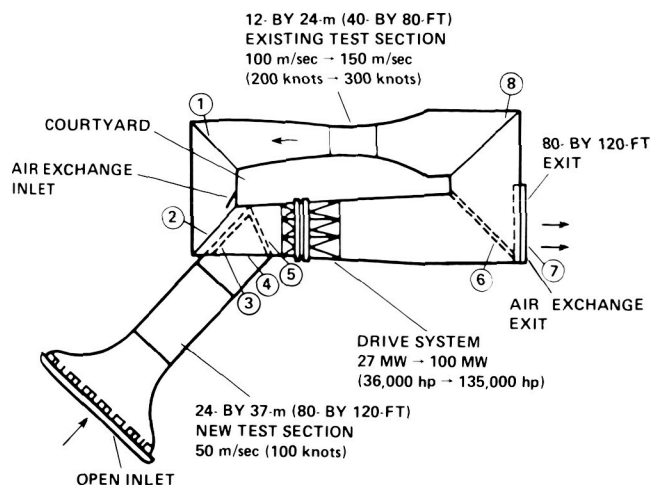


Figure 22. Planform Drawing of 40- by 80-Foot and 80- by 120-Foot Wind Tunnels

40- by 80-Foot Wind Tunnel

The 40- by 80-Foot Wind Tunnel is a closed-return tunnel with a closed test section that is 40 ft high, 80 ft wide, and 80 ft long. The test section is lined with 6 in. of sound-absorptive material to improve the quality of acoustic measurements.

It has been used for testing fighter aircraft, lifting-body configurations, large-scale supersonic transport and Space Shuttle models, V/STOL and STOL aircraft and models, advanced rotor systems and rotorcraft, jet-engine noise-suppression systems, and a variety of other test items such as parachutes and radars. With its speed capability of approximately 300 knots, it is especially valuable for testing new, high-speed rotorcraft concepts.

80- by 120-Foot Wind Tunnel

The 80- by 120-Foot Wind Tunnel, the world's largest, is an open-circuit tunnel that uses the same 106-MW drive system as does the 40- by 80. Because of its size, the 80- by 120 will make it possible, for the first time, to test full-scale rotor systems and powered-lift aircraft at very low forward-flight speeds without significant wind tunnel wall or floor effects.

10. FIRST JET-STOL TRANSPORT AIRCRAFT-AUGMENTOR WING

The powered-lift, ejector-augmentor concept was demonstrated as a powerful lift-enhancing device on a highly modified DHC-5 Buffalo turboprop aircraft. The project started in 1970 as a joint U.S./Canadian (NASA/DITC) effort. The aircraft first flew on May 1, 1971 (fig. 23), and flight research

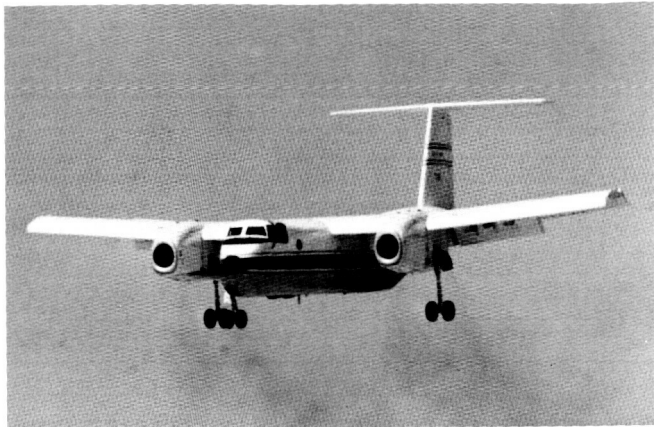


Figure 23. First Jet STOL Aircraft

continued at Ames through 1976; the aircraft is now in Canada.

The Augmentor Wing successfully demonstrated the augmentor concept, achieving thrust-augmentation ratios of about 1.20. It was the world's first jet-STOL transport, and the concept continues to be a favored approach by some members of industry for an operational jet-STOL. The aircraft demonstrated significant gains in C_L (up to $C_{L\max}$ of 5.5 and an operating C_L of 3.9), and nominal approach speeds of 60 knots were routine. Speeds as low as 50 knots were demonstrated when flying on the back side of the power curve where a reduction in speed required increased power. Takeoff and landing distances of less than 1,000 ft were routinely demonstrated, and ground rolls as low as 350 ft were achieved.

Joint NASA, FAA, and Canadian DOT investigations using the Augmentor Wing made a major contribution to powered-lift aircraft certification criteria.

C. OTHER IMPORTANT INNOVATIONS AND ACCOMPLISHMENTS OF AMES RESEARCH CENTER

Important innovations and accomplishments of Ames Research Center not included in appendices A and B are described in this appendix. They have been subdivided into astronautics and aeronautics.

ASTRONAUTICS

1. TEKTITES AND ABLATION

Description

In the 1950s H. J. Allen suggested that the study of meteorites, the reentry bodies of nature, should yield insight into the ablation properties of reentry heat shields. Dean Chapman conducted ablation studies in a wind tunnel on spheres of various frozen materials including "glycerin glass" or frozen glycerin. As confirmed by photography, the glass quickly softened and, as its surface melted into a viscous fluid, a system of surface waves appeared that were concentric about the stagnation point. Shortly thereafter it was brought to the attention of Chapman that the surface wave patterns were similar to those on tektites, thought to be a class of meteorites (fig. 24).

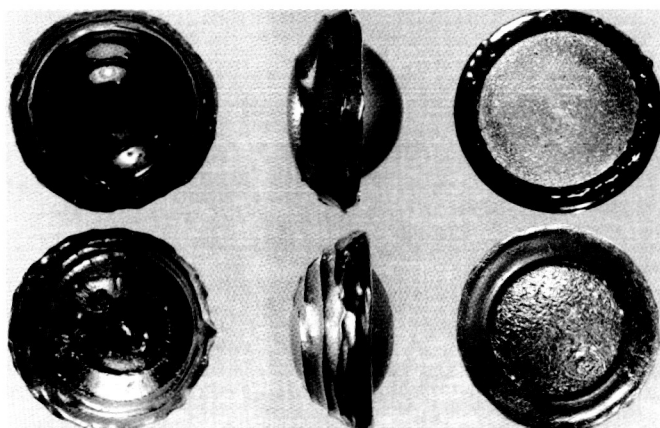


Figure 24. Comparison of Artificial and Natural Tektites

Bringing aerodynamic theories to the study of tektites, Chapman developed a hypothesis on their origin based on a study of the heating patterns displayed by the pellets' shape and a calculation of their flight speed. The origin of tektites, he suggested, was the Moon. The tektite hypothesis provided a new perspective on the materials composing the Moon and the forces that produced its craters. However, the lunar origin of tektites was opposed by many scientists, and the controversy has never been completely settled.

Significance

The study of tektites contributed significantly to the material and heat-transfer design of heat shields. This activity resulted in five applicable solutions to Shuttle problems.

2. DESIGN STUDIES OF AEROASSISTED ORBITAL TRANSFER VEHICLES

Description

Detailed missions analysis and integrated system studies have defined the technology requirements for aeroassisted orbital transfer vehicle (AOTV) designs that effectively utilize all of Earth-Moon space for reusable, space-based operations. Included are configuration optimization, aerodynamic characteristics, aerothermodynamic heating, thermal protection, structures, propulsion, volumetric efficiency, and payload capability. These analyses are based on the most complete modeling of flow-field physics possible with today's most powerful computers. It is the only work that properly accounts for the important real-gas effects that characterize the unique, rarefied, hypervelocity AOTV flight regimes and significantly impacts design requirements. The most advanced analytical methods in computational fluid dynamics, molecular physics, and chemistry were used to develop unique supercomputer codes that predict the complex interacting-flow phenomena (e.g., nonequilibrium thermochemical relaxation coupled with radiation transport and low-density viscous effects). The foregoing phenomena were synthesized with experimental work to obtain complete system designs for the conceptual stage, which resulted in two generic vehicles that satisfy many NASA/DOD mission requirements (i.e., the "aerobrake" AOTV for high-altitude orbital-change missions and the "aeromaneuvering" AOTV for low-Earth-orbit sorties involving large plane changes (fig. 25)).

Significance

This pioneering work is the nation's pacesetter for advanced space transportation systems and is of critical importance to national programs, NASA's goals, and the scientific community. It is essential for the success of the Space Station, the national aerospace plane (NASP), and the military transatmospheric vehicle (TAV) programs. Major advances have already redirected large-scale research efforts in government and industry and have saved large expenditures in R&D funds and time. For example, derivatives of the Ames designs now significantly influence research efforts in

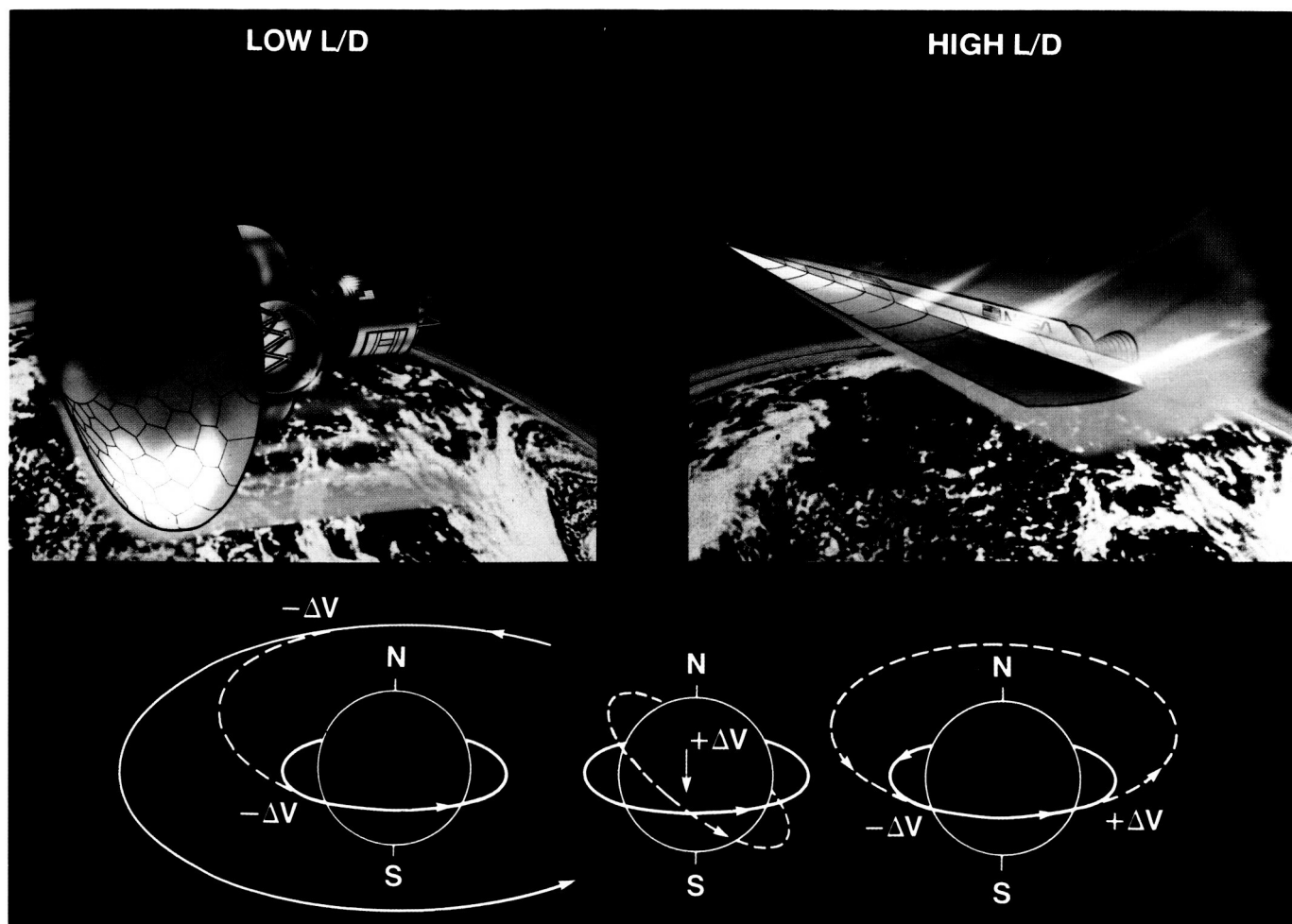


Figure 25. Aeroassisted Orbital Transfer Vehicle Concepts

NASA and in industry. Furthermore, the Ames work has enabled the definition of critical science issues and provides the principal guidance for international experts engaged in research in this new area.

3. STRUCTURE OF UNKNOWN PLANETARY ATMOSPHERES

Description

It was recognized in the mid 1960s by researchers at Ames (in particular, Al Seiff and Vic Peterson) that a probe entering the atmosphere of a planet could determine the structure of the atmosphere of that planet. What is meant by structure is the ambient density, pressure, and temperature of the atmosphere of that planet. Since the probe entry velocity would be very high, no direct-measuring sensors could be

deployed, but the innovative idea was to make use of accelerometers. Given a knowledge of the aerodynamic characteristics, together with deceleration measurements, the atmospheric density can be calculated from an arbitrary entry. Integration of the density defines the pressure, and the equation of state yields the temperature, given the molecular weight of the atmosphere from other instruments aboard the probe. The probe aerodynamics must be calibrated before flight over wide ranges of Mach number and Reynolds number and in gases similar to those in the atmosphere to be encountered.

Significance

The concept was first tried in the Earth's atmosphere in 1971 with the flight of the Planetary Atmosphere Entry Test (PAET) probe, which was launched from Wallops to a high altitude, then accelerated back into Earth's atmosphere. The deduced results were compared with data from conventional

meteorological soundings and the agreement was almost perfect. This success led to the inclusion of this experiment (called the Atmosphere Structure Experiment) on the two Viking missions to Mars (1976), the four Pioneer Venus probes (1978), and the Galileo probe mission to Jupiter (scheduled for launch in 1986, but postponed). The best definition of the structure of the atmospheres of Mars and Venus are from the results that were obtained by this technique.

4. ABLATING HEAT-SHIELD DESIGN

Description

In 1958, Rubesin and Pappas developed a theory for the behavior of a turbulent boundary layer experiencing surface transpiration. It was demonstrated that surface transpiration is an extremely effective means of reducing both skin friction and aerodynamic heating, and that light gases are more effective than heavy ones. This theoretical finding led to an experimental program in transpiration cooling with foreign gas injection, which culminated in a report by Pappas and Okuno that showed the earlier theory to be substantially correct. Although active transpiration cooling was not adopted as the thermal protection system for the nose cones of that time, designers of passive ablation systems used the theory and experimental results obtained at Ames to provide estimates of the effectiveness of the various gaseous constituents of the ablation products to reduce the incoming heat flux prior to its being absorbed through surface phase change.

Significance

The theory was used in the design of many of the nose cone heat shields produced in the 1960s.

5. ADVANCED SPACEBORNE INFORMATION-MANAGEMENT SYSTEMS

Description

Since 1963, with the formation of the development directorate, NASA Ames has made significant contributions to space research through the development of advanced information management systems for efficient data processing in spaceflight applications. Typical examples of these contributions are

- System telemetry simulator for rapid checkout and calibration of the Pioneer Ground Operational Equipment (GOE) at the Deep Space Net and of the PAET probe

- Convolutional coder for the Pioneer 9 Spacecraft, which established the use of convolutional error correction codes for deep-space planetary missions
- Systems computer models of the Infrared Astronomical Satellite (IRAS) Telescope System which led to rapid development and evaluation of the IRAS/JPL data-processing algorithms
- Real-time command and control systems for the Solar Pointing Aerobee Rocket Control System (SPARCS) Program, which served as a national facility for atmospheric research scientists
- ARC/CDF Fire Weather Data System, which led to the establishment and integration of remote, fire-weather, data-collection stations throughout California to develop fire-weather prediction and forecasting models
- Infrared imagery of the Shuttle (IRIS) experiment which led to the thermal imaging of the Shuttle during reentry
- CV-990 sunphotometer experiment, which led to the first ground-truth validation of the SAGE satellite sensors/data

Significance

Integration of future artificial intelligence (AI) technologies, especially in the area of expert systems, into information-management systems will lead to the development of intelligent machine systems capable of reasoning, planning, scheduling, diagnosing fault, monitoring, simulating, and providing system design analysis/advice.

6. LUNAR MAGNETIC OBSERVATORIES

Description

Four stationary and two portable magnetometers were developed for the Apollo lunar landing program. The four stationary magnetic observatories utilized a stored program to automatically perform a site survey, had a digital filter to limit the alias error, and used new ring core fluxgate sensors.

Significance

These magnetic observatories made the first measurements of a permanent magnetic field on the Moon, and measured the electrical conductivity and temperature profile of the lunar interior, the magnetic permeability and iron content of the Moon, and the lunar field interactions with the solar wind. The results led to the development of an orbiting satellite to map the permanent lunar magnetic fields and opened a new field of research for studying remnant fields on other magnetized bodies in our solar system.

7. BONE-STIFFNESS ANALYZER

Description

An instrument utilizing a new, painless, noninvasive technique for quickly and accurately measuring bone mass and stiffness has been developed and is in routine use.

Significance

This instrument will not only provide important information about bone loss during long-term spaceflight, but may also aid in treating bone fractures and bone-weakening disease, including early diagnosis of osteoporosis.

8. VESTIBULAR RESEARCH FACILITY

Description

A vestibular research facility which can deliver precise rotational and linear accelerations to animal test subjects has been designed and constructed (fig. 26). This facility is providing baseline data for a future Spacelab vestibular research facility.



Figure 26. Vestibular Research Facility

Significance

This facility, which is a unique national resource for the conduct of neuroscience research, will make possible advances in understanding the body's biological "inertial guidance system" and how it functions in space. Thus, it may help solve the vexing problem of space motion sickness.

9. LUNAR-LANDING RESEARCH VEHICLE

Description

The lunar-launching research vehicle (LLRV) is a piloted free-flight simulator designed to simulate landing on the lunar surface in support of the Apollo program. Its purpose was to provide a realistic training tool that Apollo astronauts could use to prepare for manned lunar landings with their attendant high pilot workload and psychological stress. A jet engine supported five-sixths of the LLRV's weight; rockets lifted the remainder, simulating the descent propulsion system of an actual lunar landing (fig. 27). Attitude-control thrusters allowed the pilot to control the vehicle; aerodynamics played no part.

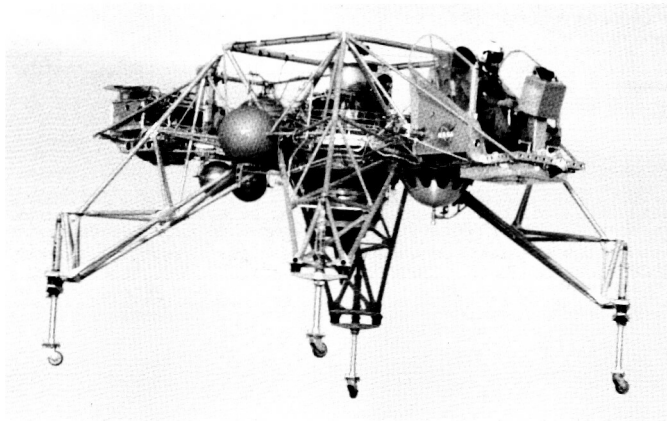


Figure 27. Lunar Landing Research Vehicle

Significance

The LLRV yielded important information on vehicle handling qualities and piloting techniques and procedures necessary for a successful lunar landing. The vehicle contributed much to the U.S. effort in achieving a successful manned lunar landing. All primary and backup Apollo astronauts trained on the LLRV in preparation for their actual missions.

10. VIKING-LANDER BIOLOGY EXPERIMENT

Description

The Viking Lander Biology Gas Exchange Experiment was developed at Ames to conduct NASA's first remote search for extraterrestrial life on Mars — the next most likely planet in the solar system after Earth to harbor life. The Gas Exchange Experiment, one of three Viking "life detection" instruments, was a small chemical laboratory which used a gas chromatograph to measure the gas respiration (production and assimilation) of the Martian soil upon treatment with biological nutrients.

Significance

The Gas Exchange Experiment instrument performed flawlessly and produced the first evidence of the unique and highly reactive chemical nature of the Martian soil, although no direct evidence for extant life was obtained. Further, the experiment showed the ubiquitous nature of the Martian, hostile-to-life surface material by demonstrating its presence in multiple samples at both lander sites. These data now play a fundamental role in the study of Mars as a possible birthplace of life and in the planning of advanced missions to continue the exploration of Mars and search for extant life or its fossil remains. The experiment additionally formed the foundation for other flight experiments and instruments, notably the Pioneer Venus Gas Chromatograph which first discovered the oxidative nature of the Venusian atmosphere. Based on this heritage, a new instrument — the Cometary Ice and Dust Experiment — is being developed at Ames to make the first *in situ* determinations of the volatile and organic chemical nature of cometary dust and ices.

11. AMES SPACE SUIT DEVELOPMENTS

Description

The Ames Research Center has an ongoing development program to address extravehicular activity (EVA) space suit technology issues for advanced space missions. Since 1964, Ames has developed a series of suit concepts (Ames AX-1, AX-2, AX-3, AX-5) which have been designed to meet projected mission requirements. Elements of these suit concepts have provided technologies which are currently used in the Space Transportation System Extravehicular Mobility Unit (STS EMU) and also demonstrate technologies applicable to meet Space Station EVA needs.

The Ames AX-1 and AX-2 suits were designed to be used for extended lunar operations. A single-axis waist and rotary-bearing-joint system demonstrated in the AX-2 is currently used in the STS EMU. The AX-3 hybrid suit was developed to demonstrate high-pressure space suit technology (fig. 28).

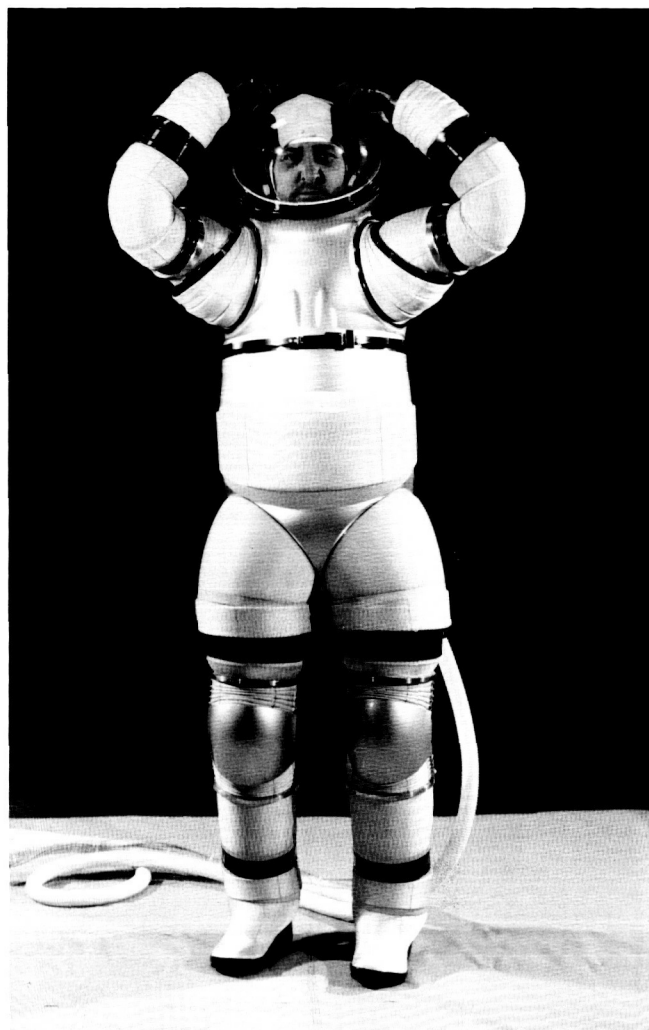


Figure 28. AX-3 Space Suit

A unique, low-leakage, low-torque bearing was developed for the AX-3 and is also used in the STS EMU. Based on the AX-3 design, a collaborative effort between Johnson Space Center and Ames has produced the Zero Prebreathe Suit (ZPS), which is a candidate concept for the Space Station initial operating configuration. Current development of the AX-5 Hard Space Suit (fig. 29) is to enhance EVA capabilities for Space Station. The AX-5 suit can operate at internal pressures up to 1 atm, provides for improved mobility and hazard protection, incorporates a quick-change sizing capability and is designed for minimal manufacturing, maintenance, and operations costs.

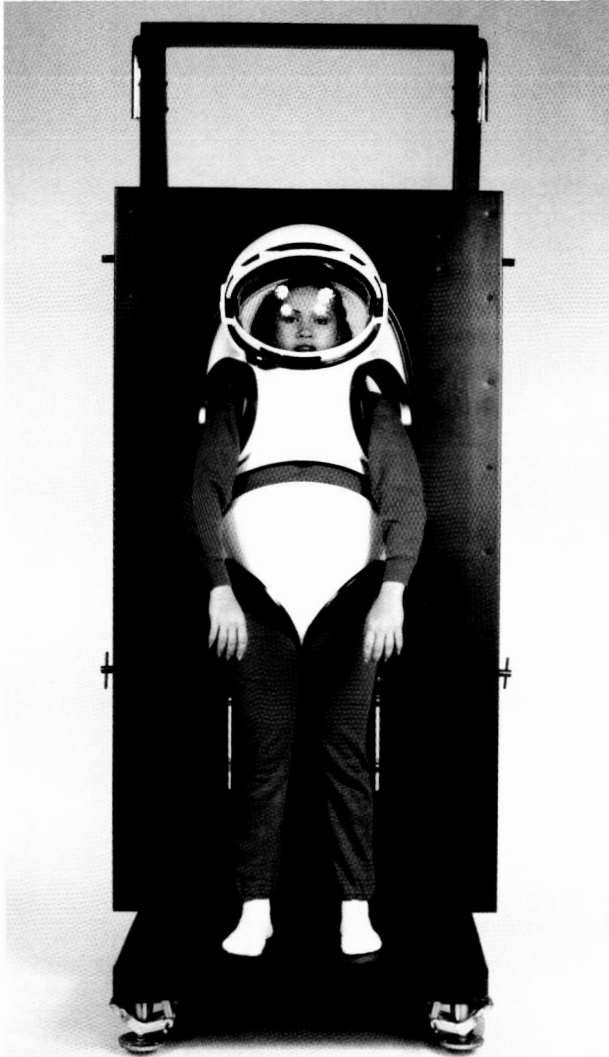


Figure 29. AX-5 Space Suit Torso Mock-up and Donning Stations

Significance

What the astronaut can accomplish in space has been greatly increased by the development of reliable space suits.

12. AMES LUNAR SCIENCE

Description

Using a unique lunar sample return analysis facility at Ames, scientists studied the biology and carbon chemistry of lunar samples from Apollo flights and demonstrated conclusively that lunar soils do not contain life. This significant finding prompted investigators to ask why there was no life and what kind of carbon chemistry was taking place in its absence. They found that lunar soils were bombarded by micrometeorites and by the solar wind (the stream of atomic particles ejected by the Sun). Thus, the Moon's soil has a carbon chemistry which is dominated not by life, as it is on the Earth, but by the energetic interactions of the Sun, the Moon, and cosmic debris (fig. 30).

Subsequently, the Ames staff showed that there is virtually no carbon or nitrogen in lunar surface rocks. This indicated that the Moon has much less of these biologically critical elements than does the Earth, a circumstance which likely precludes any chance of life having ever existed on the Moon.

Significance

These discoveries describe the chemistry of a lunar "non-biosphere" which contrasts sharply with Earth's environment and helps us to better understand our own biosphere's origins and requirements.

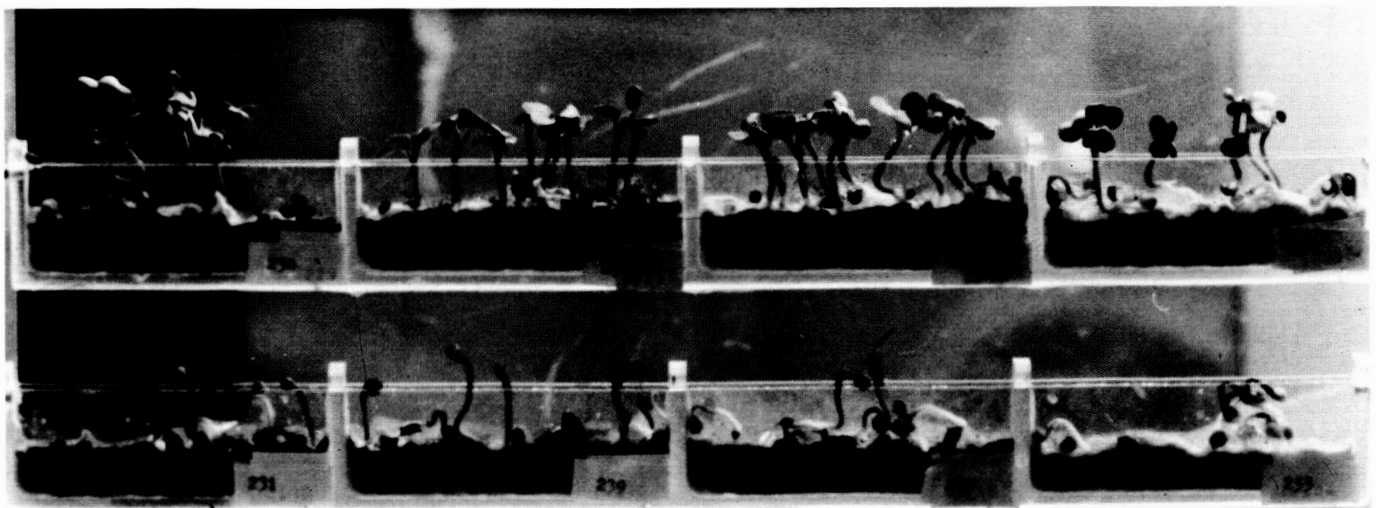


Figure 30. Spinach and Radish Plants in Lunar Soil

13. SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

Description

As a result of modern theories of stellar evolution and of the early origin of life on Earth, many scientists today are convinced that the universe is teeming with life, much of it intelligent. A million advanced cultures in our galaxy is not an unreasonable guess. Through a series of design and feasibility studies, workshops, and science working groups, Ames established the NASA search for extraterrestrial intelligence (SETI) effort to determine the most appropriate method to search for evidence of such extraterrestrial intelligent life. The only way to discover this life seems to be to detect the radiation it produces, either for its own purposes or in a deliberate attempt to signal us (fig. 31).

Significance

Such equipment represents a significant advance in the state of the art, and it is very likely that it will yield valuable byproducts in radio astronomy, large-scale data analysis, and other fields. Most important, in the words of the Field Committee report, *Astronomy and Astrophysics for the 1980's*: "It is hard to imagine a more exciting astronomical discovery or one that would have a greater impact on human perceptions than the detection of extraterrestrial intelligence."

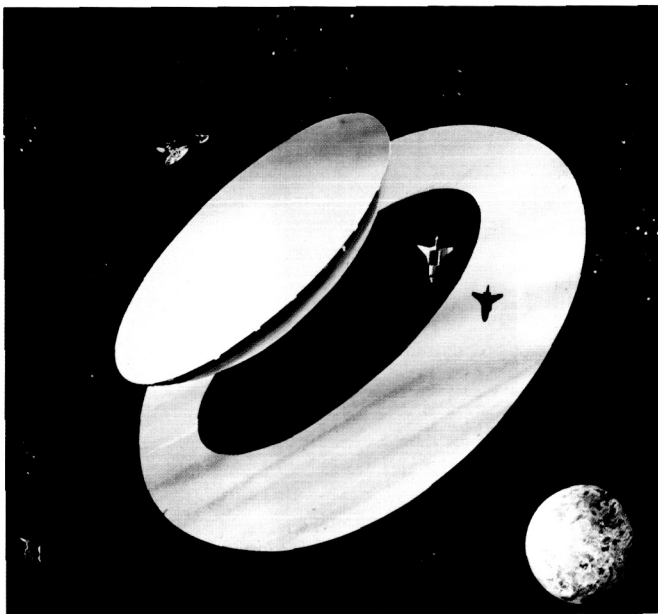


Figure 31. SETI 300-Meter Dish

Other radio astronomers around the world have used existing equipment to perform small-scale searches of the microwave spectrum for telltale coherent signals that may have been radiated by other civilizations. The Ames SETI program has designed and will construct signal-processing equipment which is capable of resolving 10 MHz of spectrum into 10 million channels simultaneously in real time. This high-resolution, multichannel analyzer will be used with current radio telescopes to "listen" with great sensitivity to such nearby stars as our Sun and also to scan the entire sky for more powerful signals. The resulting coverage will be 100,000 times the bandwidth of all previous searches and billions of times more comprehensive.

AERONAUTICS

1. DIGITAL ELECTRONIC ENGINE CONTROLS SYSTEM

Description

The digital electronic engine controls (DEEC) system is a full-authority digital system that controls the 10 variables on the F100 engine that powers the F-15 and F-16 airplanes. It provides new control modes, improved control accuracy, fault detection and accommodation, and simplified hardware. It was first flown on the NASA F-15 in a joint NASA/Air Force program in 1981.

Significance

The DEEC has greatly improved the F100 engine; higher thrust, faster throttle response, stall-free operation, improved afterburner operation, and greatly improved (to a factor of 8) reliability and maintainability. DEEC entered production in late 1985.

2. HELICOPTER DESIGN CODES

Description

Various computer codes for aerodynamics have been developed at Ames, including CAMRAD and ROT22. CAMRAD is a comprehensive helicopter analysis code accommodating such rotor configurations as tandem, counterrotating (ABC), and tilt rotor, and is used to predict performance, blade loads, and aeroelastic stability. ROT22 is a rotor flow-field code. It is three-dimensional, full-potential, transonic, and quasi-steady, and can be used from hover to forward flight.

Significance

These computer codes are utilized for rotor design and for predicting helicopter and rotor performance. They are being used by other government agencies, universities, and industry. The CAMRAD code was used by industry for predicting performance and other parameters during the development of the J VX aircraft.

3. FUEL-EFFICIENT FLIGHT-PROFILE ALGORITHMS

Description

A set of advanced guidance algorithms was developed that takes inputs from an aircraft system and its environments, operates on them in a practical manner, and provides the cockpit crew with information that optimizes performance management of the aircraft.

Significance

Because of their ability to minimize fuel consumption and direct operating costs, these systems have become as essential to new transport aircraft as autopilots and navigation systems. Systems utilizing these algorithms have been installed in commercial aircraft, including the 757, 767, and A310. The airlines have estimated that these systems provide up to 4% saving in fuel consumption.

4. FREE-TIP ROTOR

Description

Ames has developed a 10%-span, free-tip rotor model to investigate its potential for reducing flight loads and increasing performance. With this concept, the tip is free to pitch about its own axis, which is forward of the aerodynamic center.

Significance

Research with the free-tip rotor has shown a significant decrease in power requirements at cruise speed, with an increase in lift of 16%. The peak vibratory blade loads were reduced, as were vibratory control loads.

5. QUIET, SHORT-HAUL RESEARCH AIRCRAFT

Description

The Quiet-Short-Haul Research Aircraft (QSRA), a proof-of-concept powered-lift aircraft, was developed to demonstrate in the low-speed regime the viability of the upper-

surface-blowing (USB) concept as a very powerful lift enhancer for STOL aircraft and to do so at a reasonable cost. It utilizes a highly modified DHC-5 Buffalo, but has an entirely new wing, designed to emulate a Mach 0.74 supercritical airfoil, although the aircraft itself is limited to low-speed, terminal-area research flying (fig. 32). The QSRA has achieved very high C_L s (operational C_L of 5.5 and a C_{Lmax} of 11) and is routinely flown at approach speeds as low as 60 knots, significant for a wing loading of 80 lb/ft². This four-engine aircraft flies easily on three engines and can be flown on two engines. The aircraft first flew on July 6, 1978, and is available today as a Powered Lift Flight Research Facility (fig. 32).

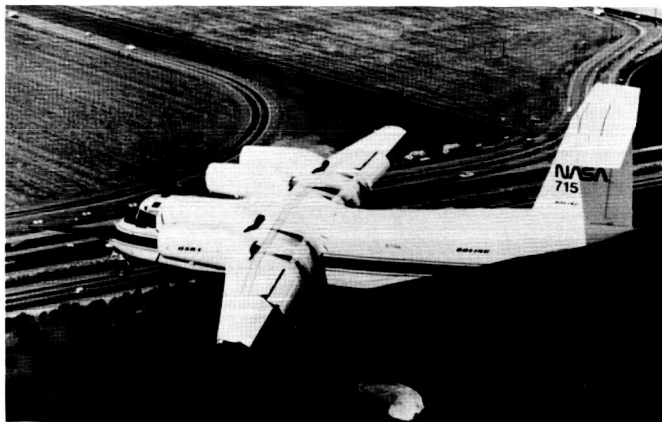


Figure 32. Quiet, Short-Haul Research Aircraft

Significance

The QSRA has proved the USB concept for the four-engine configuration in the low-speed regime. The application of USB to military needs, both Navy and Air Force, was demonstrated. During carrier trials aboard the Kitty Hawk with a wind over the deck of 30 knots, takeoff distances of less than 300 ft and landing distances of less than 200 ft were achieved. For Air Force applications on partially bombed runways, takeoff in less than 700 ft and landing in less than 800 ft without thrust reversers and with zero wind conditions were demonstrated. The real payoff, however, may be the added flexibility of a significantly increased payload — up to 25%.

The QSRA achieved a real milestone in noise abatement, easily meeting the FAR 36 requirements. It recently flew demonstrations at the noise-sensitive Monterey, California, airport and was undetected by either local residents or the airport's monitoring microphones. It is a concept championed by a significant and growing part of the aeronautical community.

6. X-WING, ROTOR-SYSTEMS RESEARCH AIRCRAFT

Description

The X-Wing (Rotor-Systems Research Aircraft (RSRA)) concept promises the first convertiplane vehicle that will provide rotary-wing VTOL capability combined with fixed-wing, high-subsonic (Mach 0.8) turbojet performance. The concept employs a symmetrical airfoil in a four-blade "X" arrangement. Lift and control moments are provided by circulation control introduced through leading- and trailing-edge slots in the blades to give the desired wing aerodynamic flow. The flow is varied about the azimuth by a valving arrangement that controls the amount of air feeding into each blade slot. In November 1982, sufficient engineering R&D had been conducted by DARPA, NASA, Navy, and industry to launch a joint project to develop and flight-test a large X-Wing rotor system. It was decided to conduct the investigation with one of Ames's two RSRAs (fig. 33) and take advantage of the fixed wing and load-measuring capabilities of the vehicle's design. The vehicle is currently undergoing modification to accept the X-Wing Rotor System and the Vehicle Management System. The first flights in the fixed-wing configuration are scheduled to occur in 1986, after which rotary-wing flights will be made; subsequently, the all-important in-flight conversion from rotary-wing to fixed-wing flight will be made. This is predicted to occur most effectively in the 180- to 210-knot range.



Figure 33. Rotor Systems Research Aircraft

Significance

The X-Wing concept promises the first low disc loading (high hover efficiency) VTOL vehicle with high subsonic turbojet cruise capability that does not require auxiliary propulsion or lifting devices. The X-Wing provides the lift in all modes of flight, and in an operational configuration, the convertible engine will divide its power between the rotor and exhaust thrust as required.

7. AERODYNAMIC DESIGN UTILIZING NUMERICAL OPTIMIZATION

Description

In the early 1970s, it became apparent that emerging computational fluid dynamics (CFD) codes would be valuable in analyzing complex aerodynamic flows. However, the use of these codes for aerodynamic design was largely a trial-and-error process, not unlike the approach that would be taken if purely experimental methods were to be used to develop an aircraft design. At nearly the same time the new CFD codes were being developed, advances were being made in the theory of numerical optimization, particularly with application to structural problems. Researchers at Ames (Murman, Van der Platts, and Hicks) developed the concept of combining numerical optimization and aerodynamic analysis to provide the capability of specifying desired aerodynamic performance and generating an optimum configuration to provide that performance through numerical optimization.

Significance

The development and the distribution of the CFD concept to every major aircraft company has had a profound effect upon aircraft design. For the first time, aircraft configurations can be developed computationally to provide desired performance. Wing design has been reduced from a very expensive, time-consuming process involving wind tunnel tests of several configurations to a process that involves designing wings computationally and conducting a wind tunnel test of the design to verify its performance.

8. HIMAT, REMOTELY PILOTED RESEARCH AIRCRAFT FOR HIGH-MANEUVERABILITY RESEARCH

Description

A subscale, remotely piloted research vehicle approach was conceived to evaluate, in flight, new technologies which, when combined, offered substantial improvement in fighter maneuverability. The technologies included close-coupled canards, aeroelastic tailoring, relaxed static stability, and digital fly-by-wire.

Significance

This was the first use of a sophisticated, unmanned, research vehicle to evaluate high-risk technologies applicable

to a manned fighter. The interactions among the new technologies were key to providing the overall maneuverability improvements. The cost was much less than a manned research vehicle would have been, yet the contribution to advancing fighter technology has been substantial.

9. WORLD-STANDARD AIRCRAFT-PARAMETER-ESTIMATION TECHNOLOGY

Description

An analytic method and series of software programs was developed to extract the aerodynamic stability derivatives from flight data. The program is based on maximum-likelihood estimation theory, and is applicable to a wide variety of dynamic systems.

Significance

The maximum-likelihood estimation program enables a user to obtain highly accurate estimates of aircraft aerodynamic, propulsive, and performance characteristics from flight-dynamic time-history data. This approach, and the software program itself, is now used worldwide for acquiring aircraft characteristics from flight data for aerodynamic model validation, simulator updates, control-system design, flying-qualities-criteria development, and for understanding phenomena observed in flight.

10. FAULT-TOLERANT SOFTWARE

Description

A fault-tolerant software system was developed and demonstrated on the F-8 digital fly-by-wire aircraft. It can detect and recover from otherwise catastrophic software errors which would affect all redundant computer channels. The approach is called resident backup software.

Significance

Multiple-channel, digital fly-by-wire (DFBW) systems are susceptible to common-mode software errors that would affect all redundant channels alike, thus defeating the hardware redundancy provided. The resident backup software technology provides a means of surviving a large class of software errors without having to provide an independent hardware backup system. This approach reduces system cost and complexity. The approach has been adopted by several advanced aircraft programs utilizing DFBW systems.

11. MAJOR ADVANCE IN HIDDEN-LINE ALGORITHM

Description

A highly efficient and accurate algorithm was developed for computer-aided design and engineering programs which proved to be vastly superior than existing codes in terms of execution speed (cost) and in its ability to handle large, complex models correctly.

Significance

The new software code has become the best-selling NASA software package ever handled by COSMIC, and has been applied with overwhelming results in aircraft, architectural, and systems design by government and industrial concerns. The cost savings and improvement in execution speed represents a national productivity improvement.

12. FLIGHT-TEST-MANEUVER AUTOPILOT CONCEPT

Description

A desired flight-test maneuver is programmed into a digital computer, then used to command the test airplane through the test maneuver automatically. The autopilot commands the normal flight-control system, so there is no need for additional actuators or other expensive hardware. The pilot can override the automatic system at any time, thereby reverting back to the normal flight-control system.

Significance

Test maneuvers are frequently difficult piloting tasks because a combination of test variables must be obtained simultaneously to achieve the necessary test conditions. With the use of the flight-test-maneuver autopilot, the plane can be brought to conditions much faster, and repeatability between conditions is greatly improved. Fewer repeat points are necessary. The net result is a substantial decrease in the flight time required to obtain the desired quantity of test data.

13. REMOTELY AUGMENTED VEHICLE TEST CONCEPT

Description

In nearly all flight vehicles today, the flight-control system augments the basic airplane to provide acceptable handling characteristics. The remotely augmented vehicle concept provides this control augmentation through ground-based digital computers connected to the airplane through an up/down telemetry system. The sensors that are required for collecting research data provide the necessary inputs into the computer for control augmentation.

Significance

Various control/augmentation concepts can be easily and safely evaluated in flight while making use of the same computers located at the ground facility. Because the facility can be shared across multiple projects, and because it uses common computer peripherals that facilitate programming and checkout, there is a significant savings in preparation time and program cost. Also, advanced-technology computers that are not yet available in flight-qualified packages can be utilized in the laboratory environment. As an example, the latest AI computers can be evaluated in a flight application, even though it will be several years before a version of that computer will be available in a flight configuration.

14. COMPOSITE AEROELASTIC TAILORING FOR TRANSONIC MANEUVERING

Description

Composite aeroelastic tailoring is the use of composite wing construction with ply-layup of the composite materials such that the "wind" causes the wing to twist a desired amount as airloads are applied. Thus, the wing has the optimum camber and twist characteristics at the design maneuvering g-load for maximum performance, and has a different, but optimum, twist at 1-g cruise flight that provides maximum performance at that condition.

Significance

The use of composite materials in this manner provides a lighter-weight, higher-performance vehicle. The successful flight demonstration of this concept, and the test technique that provides accurate measurement of the twist under air loads during flight, makes the technology highly beneficial for future fighter aircraft. For example, the X-29A design draws heavily on the experience gained from the HIMAT demonstration of aeroelastic tailoring.

15. UNPOWERED-LANDING-APPROACH TECHNOLOGY

Description

Unpowered approach and landing is a technology that has existed since the first aircraft engine failure. The technology was significantly advanced during the "X" series of rocket-powered research aircraft and the lifting-body program flown at the Dryden Flight Research Center from the late 1940s until the mid-1970s. These aircraft were powered by a rocket engine fired for a limited duration; they then glided to an unpowered approach and landing. Techniques were developed to safely accomplish unpowered landings in vehicles with extremely low subsonic lift-to-drag ratios. These techniques were proposed for use by the Space Shuttle in lieu of the planned landing engines.

Significance

The practical gains available for a space vehicle returning to Earth that does not require extra engines and fuel for landing are most visible on the Space Shuttle Orbiter. The initial and operating costs due to the added complexity, reliability, etc., are considerably reduced, and the weight saved can be translated directly into extra payload available to the Shuttle.

16. FIGHTER AGILITY STUDY

Description

Early national emphasis on air-to-air combat led NASA to intensify research into methods for improving the transonic maneuverability of fighter aircraft. Evaluation tools were

developed which included new techniques for evaluating airframe buffet, turn performance, and flying qualities (gun-sight tracking task and analysis). These tools provided a means for evaluating the use of maneuver flaps and control-system advancements, and for basic studies in new airplane configurations. Later efforts were made to combine these evaluation tools. The emphasis was on aerodynamic performance, maneuver performance, and precision controllability to achieve improved aircraft agility.

Significance

The agility study provided an analysis technique which provided an understanding and overall assessment of aircraft maneuverability. The early studies provided research data and flight-test techniques which were used in the development of many present-day aircraft designs. The resulting methodology also provides a tool which is useful for optimizing the configuration of a particular airplane, and with appropriate modifications it can be used as a measure of the "air superiority" of different aircraft.

17. TRANSITION-CONE FLIGHT EXPERIMENT

Description

The transition of boundary-layer flows from laminar to turbulent and the transition location are critical and fundamental phenomena in scaling model results to full scale. Transition and fluctuating pressure data acquired on a standard body (Arnold Engineering Development Center Transition Cone) using the same instrumentation and technique over a wide range of Mach numbers and in a number of European wind tunnels were evaluated. Flight data were obtained with the cone mounted in front of the nose of an F-15 aircraft.

Significance

The flight data from this experiment are unique in that they were obtained in a nearly noise-free environment. They are the world standard by which the quality of wind tunnel flow is judged. The data from this experiment are used to assess the effect of wind tunnel noise on Reynolds number scaling and to help achieve better correlation between wind tunnels and between wind tunnel testing and flight.

18. LASER SPECKLE VELOCIMETRY

Description

One of the most difficult problems in experimental fluid dynamics has been the measurement of the vorticity field in fluid flows. The currently available velocity-measurement techniques (e.g., hot-wire or LV) are sensitive only to the local velocity. Recently, a novel flow-velocity-measurement technique, commonly known as Laser Speckle Velocimetry (fig. 34), has been developed. This technique provides the visualization of the two-dimensional streamline pattern in an unsteady flow as well as the quantification of the instantaneous velocity field. A plane of interest in the fluid, seeded with microparticles as scatterers, is illuminated by a coherent light source, usually a pulsed laser. When the plane is imaged through a lens onto a photographic film or plate, the statistically scattered light produces a speckle pattern. In usual

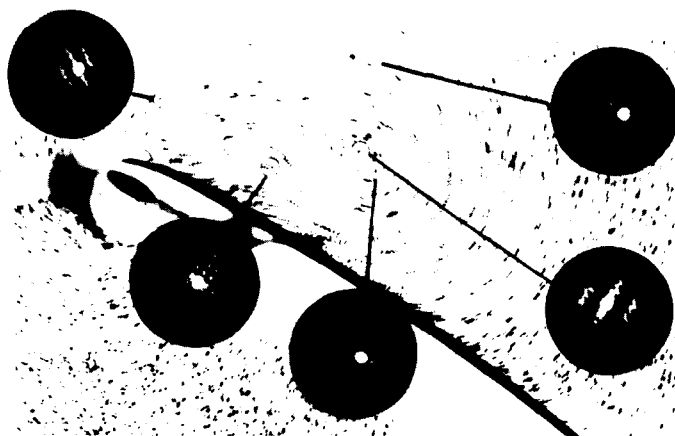
speckle photography, two or more such speckle patterns are superposed on the same photographic plate, resulting in a "specklegram." Through the appropriate choice of the time interval between exposures, information on the local particle velocities is stored on the specklegram and may be transformed to a fluid-flow pattern through microscopic inspection.

Significance

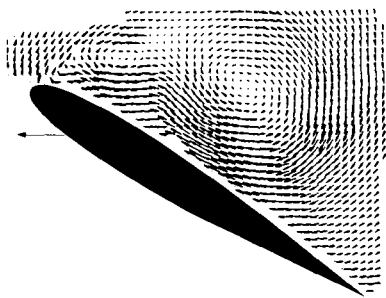
The main advantage of this new technique is that the entire two-dimensional velocity field can be recorded in a single measurement with great accuracy and spatial resolution. From this measurement, the instantaneous vorticity field can be obtained easily and directly. This constitutes a great asset for the study of a variety of flows that evolve stochastically in time and space, such as the unsteady vortical flows in rotorcraft aerodynamics.

- ACCURATE MEASUREMENT OF FLOW FIELDS, QUICKLY AND EFFICIENTLY
- MEASURE VELOCITY FIELD OVER ENTIRE PLANE FROM SINGLE PHOTOGRAPH
- IDEALLY SUITED TO UNSTEADY AND VORTICAL FLOWS
- HIGH SPATIAL RESOLUTION; STREAMLINES AND VORTICITY CONTOURS EASILY DERIVED
- AUTOMATIC DATA ANALYSIS THROUGH DIGITAL IMAGE PROCESSING

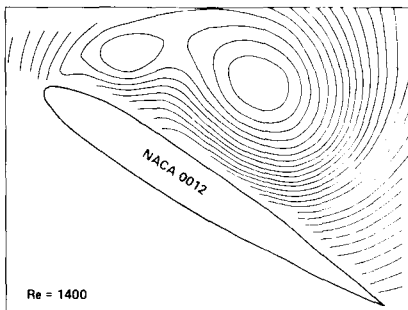
FLOW PAST WING AT HIGH ANGLE OF ATTACK



VELOCITY VECTOR MAP OF FLOW OVER AN AIRFOIL
NACA 0012



STREAMLINES OF FLOW OVER AN AIRFOIL



VORTICITY CONTOURS OF FLOW OVER AN AIRFOIL

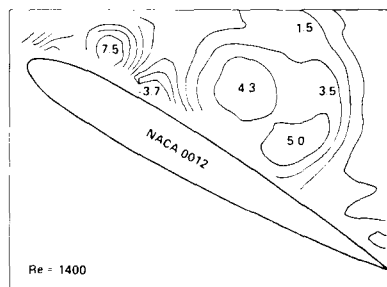


Figure 34. Laser Speckle Velocimetry

19. CONICAL CAMBER

Description

In the early 1950s several aircraft were developed that used simple delta wings to obtain adequate lifting surface area and yet could attain supersonic flight. A particular problem with these aircraft was the high transonic drag associated with a simple delta wing. Researchers at Ames Research Center, chiefly Charles Hall, developed the concept of conical camber wherein the camber of the leading edge was increased conically along the leading edge. Significant reductions in the transonic drag of delta wings were achieved through this technique.

Significance

This concept was applied to two aircraft that were operational in the late 1950s and throughout the 1960s, the F-106 and the B-58. Without the application of the concept, these aircraft could not have met their required performance levels.

20. AIRCRAFT FIRE SAFETY; IMPROVED SEATS

Description

Aircraft seat flammability and egress time are important factors for passenger safety in aircraft fires. An advanced aircraft passenger and crew seat was developed for use in commercial and military transport aircraft. The seat is extremely fire-resistant and offers increased egress time from an aircraft involved either in a post-crash or in-flight fire. The seat consists of the conventional urethane foam, which is currently used, enveloped in a fire-blocking layer consisting of an aluminized or nonaluminized fabric which is thermally stable and fire-resistant. These seats were successfully tested in full-scale tests conducted by the FAA using the C-133 aircraft and by NASA and the FAA using the B-720 aircraft in the Controlled-Impact-Demonstration test. The new seats also meet other performance requirements such as ease of fabrication, durability, comfort, low weight and good in-service maintenance.

Significance

As a result of the advanced seat development, the FAA issued on October 28, 1984, a new federal regulation, FAR14CFR25.853 Appendix F, Part II, "Flammability of Aircraft Seat Cushions." The new seat allows approximately 60 additional seconds of critical escape time for passengers in

post-crash fires. Transport aircraft weighing 12,500 lb or more having 30 or more seats are affected by the new regulation. All of these aircraft are to be retrofitted by October 1987. Already many airlines (United, Eastern, Air Canada) are using the new seats in their fleets. The cost of using these advanced seats is approximately \$22 million, but this cost is more than offset by the estimated 22-25 lives which will be saved each year as a result of this innovation. Approximately 600,000 seats are currently being retrofitted with the fire-blocking system in both commercial and military-transport aircraft.

21. ROTATING-CYLINDER-FLAP RESEARCH AIRCRAFT

Description

A highly modified OV-10 aircraft was used to demonstrate the rotating-cylinder-flap concept as a lift-enhancing device for STOL operation by installing the flap on the trailing edge of an OV-10 wing. The aircraft modification involved connecting the two engines through cross-shafting for engine-out capability at the lower operating speeds (i.e., V_S reduced to a point at which V_C was critical). The propeller diameter was reduced and the wings were shortened. The gross weight was increased from 8,500 lb to 11,500 lb and a C_L 33% greater than the basic OV-10 was achieved. The complete aircraft was tested in the 40- by 80-Foot Wind Tunnel at Ames and was first flown in August 1971.

Significance

The installation on the OV-10 was the first flight demonstration of the rotating-cylinder-flap concept, which is a flow-entrainment and boundary-layer-energizing device for turning the flow downward and increasing the wing lift. Unlike all, or most, pneumatic BLC and jet-flap concepts, the mechanically driven, rotating cylinder required very low amounts of power; thus there was little degradation to available takeoff horsepower. It also demonstrated the validity of modifying an existing aircraft for proof-of-concept demonstration rather than building a new vehicle.

22. INVENTION AND DEVELOPMENT OF VARIABLE-STABILITY AIRPLANE

Description

In about 1948 a Grumman F6F-3 fighter airplane was modified so that its dihedral effect could be varied in flight

by servo-actuation of the ailerons in response to measured changes in sideslip angle. Later, a rudder drive system was added so that directional stability and damping could also be varied. Eventually, six lateral and directional stability and control characteristics were variable. To expand the performance envelope, this same concept was applied in succeeding years to the F-86D, F-86E, F-100C, and X-14 airplanes. Later, a Jetstar was modified into the General-Purpose Airborne Simulator (GPAS) utilizing a new model-following concept which provided improved simulation fidelity.

Significance

For the first time a variety of airplane flying qualities could be explored in flight without changing the airplane's aerodynamic design. As a result, research studies of aircraft flying qualities much improved in scope and efficiency were possible. These studies contributed to the MIL SPEC for flying qualities. Equally important, this capability made it possible to expose the pilot to the flying qualities of future aircraft by simulating in flight the aircraft's predicted stability and response characteristics. For example, the Lockheed F-104 was designed with 10° of negative dihedral as a result of variable-stability F6F-3 flight tests.

23. ANTI-ICE PROTECTION FOR AIRCRAFT

Description

Flight research was undertaken to develop and understand the requirements for ice protection for critical aircraft components, wing surfaces, controls, windshields, and tail surfaces. The installation of anti-ice systems was accomplished on a wide variety of aircraft.

Significance

The methods developed were employed on several World War II aircraft, including the B-17, B-24, and PB4Y. Later, applications were made to fighters and jet transports.

24. A PORTABLE, TACTICAL-APPROACH-GUIDANCE SYSTEM

Description

A portable, tactical-approach-guidance (PTAG) system based on a novel, X-band, precision-approach concept has been developed and flight-tested. The system is based on

state-of-the-art X-band and radar technology and digital-processing techniques. Results from the flight-test program show that PTAG has a significant potential for providing rotorcraft and tactical aircraft with a low-cost, precision, instrument-approach capability. In addition pilot tracking performance was shown to be equivalent to pilot evaluations using manual landing systems (MLS).

Significance

The PTAG technology will give the civil and military communities a portable, precision-approach capability that will increase the scope of potential landing sites, thereby providing greater versatility for various flight scenarios. The military has investigated the use of the system as a backup for ILS or MLS in a battle-damaged-runway scenario; they have also discussed its use in remote-area operations. The civil community has suggested the system be used for short-term logging or oil exploration operations in which a low-cost, portable system is desirable.

25. DEVELOPMENT OF THRUST REVERSERS FOR JET AIRCRAFT

Description

A flight-research program successfully demonstrated the effectiveness of a fully controllable thrust reverser for use as an in-flight decelerating device, for rapid flightpath control, and for decelerating during ground roll.

Significance

The principles of the system developed at Ames were applied to most first-generation jet transports for improved braking in ground roll and additionally for in-flight deceleration for the Douglas DC-8.

26. FLIGHT STUDIES OF BOUNDARY-LAYER CONTROL TO IMPROVE LOW-SPEED AIRCRAFT PERFORMANCE

Description

The use of boundary-layer control (BLC) to improve aircraft low-speed performance was developed and demonstrated through a series of wind tunnel and flight investigations. This application of BLC to the leading and trailing edges of various wing planforms resulted in significantly

reduced takeoff and landing speeds for a wide variety of aircraft.

Significance

The research led to the application of BLC to a variety of Air Force and Navy aircraft to improve their landing performance and handling qualities.

27. GENERAL AVIATION SYNTHESIS PROGRAM COMPUTER CODE

Description

The General Aviation Synthesis Program (GASP) was developed for use in predicting numerous configurations in the general aviation field. The code is used to analyze subsonic, transport-type aircraft with turboprop, turbofan, prop-fans, or internal-combustion engines. The predictions include aircraft performance, weights, noise, and costs. GASP provides rapid and efficient first-order approximations that can be used for sensitivity analyses and trade-off studies.

Significance

The GASP code was developed as a flexible tool to provide quick-turnaround solutions to configuration studies of general-aviation aircraft. The code is being used by industry for practical solutions and analyses of aircraft designs. Users include Beech Aircraft, AVCO-Lycoming, and Williams International.

28. AVIATION SAFETY REPORTING SYSTEM

Description

At the request of the FAA, the aviation safety reporting system (ASRS) program was developed to elicit voluntary reports of operational problems and human errors in the U.S. national aviation system.

Significance

In 10 years of successful operation, ASRS has received 55,000 reports and has generated several hundred analyses and studies that have led to changes in regulations, policies, and procedures in the national aviation system.

29. MAN-VEHICLE SYSTEMS RESEARCH FACILITY

Description

The Man-Vehicle Systems Research Facility (MVS RF) is a unique national facility which became operational in FY 84, providing scientists with a full-mission aircraft simulator (including all elements of air traffic control and air-ground communication/navigation, and a computer-generated out-the-window scene in each cockpit) of a current-technology transport aircraft and an advanced-technology cockpit (see fig. 18).

Significance

The many studies conducted in this facility are providing information for cockpit design, safety procedures, and other pilot-aircraft interface issues.

30. LINE-ORIENTED FLIGHT TRAINING

Description

The concept of training and testing flight crews on all the steps in the conduct of a flight, not just emergency situations, was developed by NASA Ames. Work in full-mission-simulation technology has led to an important new training technique in the air-transport community. Line-Oriented Flight Training (LOFT) involves the use of a training simulator to recreate an actual flight from point to point, during which complex problems are introduced that require high levels of crew decision-making and coordination. The difference between LOFT and traditional simulator training is that the latter is maneuver-oriented, sometimes leading to programmed responses. LOFT occurs in real time, and provides flight crews with experience in dealing with operational problems in the same realistic manner they would use in actual flight operations.

Significance

Many airlines have adopted LOFT and have found it beneficial for crew proficiency. LOFT sessions are often videotaped, allowing crew members an objective look at their behavior and performance under various operational circumstances. The technique has now been implemented in FAA regulations. The Air Force Military Airlift Command now requires this type of training for crew members of all aircraft types.

31. COCKPIT RESOURCE MANAGEMENT

Description

Cockpit resource management (CRM) refers to the utilization of all available resources — information, equipment, and people — to achieve safe and efficient flight operations. In the late 1970s and early 1980s, Ames investigators, in the course of their full-mission-simulation studies, began to realize that most aviation incidents and accidents are not due to a lack of technical skill or knowledge. Further research revealed that between 60 and 80% of all accidents appear to be due to a lack of adequate coordination or utilization of available resources. Paradoxically, most flight crew training is concentrated on the maintenance of technical proficiency. Thus, the Aeronautical Human Factors Office at Ames has been working with numerous civilian and military air-transport organizations to provide training that focuses on crew performance skills. Topic areas include management styles, leader-subordinate roles, and decision-making in stressful circumstances. LOFT is an integral part of CRM training.

Significance

CRM training guidelines developed by Ames have been incorporated in many major airline training programs and crew evaluations. The level of interest worldwide has increased to the extent that a recent Ames workshop (co-sponsored with the Air Force Military Airlift Command) was attended by over 200 people representing 80 different organizations in 14 countries.

32. WORKLOAD PREDICTION MODEL

Description

A computer-based technique for designing simulation scenarios that will impose standardized workload levels on pilots has been developed.

Significance

One task (a supervisory control simulation) is being used for pilot selection by the Air Force. Another (a decision-making target-selection task) will be used to evaluate control devices in the Shuttle. Such standardized tasks provide a sound basis for performing other research activities and for sharing experimental results across facilities.

33. AIRCRAFT AUTOMATION

Description

Automation and the widespread application of microprocessor technology to aircraft cockpits is proceeding at a rapid pace because of several technical, economic, and safety benefits offered by their use. However, experience thus far with highly automated human/machine systems suggests that these benefits are not achieved without significant cost, and may, under some circumstances, be unattainable. The purpose of recent field studies was to evaluate two approaches to flight-deck automation to determine desirable and undesirable features and characteristics thereof, and to gain insight into related issues, including training requirements, and factors determining flight-crew acceptance of advanced technology.

Significance

This work contributes to the development of aircraft automation, its effect or potential effect on reducing or changing pilot error, and suggests design philosophies for future automation systems to reduce the incidence or effects of pilot error.

34. SUPERSONIC-TRANSPORT CERTIFICATION CRITERIA

Description

Utilizing the Ames Flight Simulator for Advanced Aircraft and led by NASA, pilot/engineer teams representing airworthiness authorities and industry from the U.S., the United Kingdom, and France defined and evaluated proposed airworthiness certification criteria for civil supersonic transports (SST). Through these investigations it was possible to identify key performance and handling characteristics that differed from conventional transport aircraft, and define agreed-upon criteria and abuse test cases.

Significance

Results of this work formed the basis of many of the special conditions used by the joint airworthiness authorities in certifying the Concorde, and will be used for the certification of future SST aircraft.

35. V/STOL HANDLING QUALITIES

Description

A considerable effort has been directed toward developing aircraft concepts that combine the vertical takeoff and landing capability of the helicopter with the high-speed cruise performance of the conventional aircraft. Ames has studied the performance, stability and control (handling qualities), and operational problems of a wide variety of V/STOL aircraft using wind tunnel tests, piloted simulation studies, and flight tests. Research results showed that all V/STOL concepts had handling qualities deficiencies which seriously compromised their operational utility. These characteristics resulted from the lack of an adequate handling qualities specification upon which to base the design. From the background of information gathered from the various research programs, Ames produced the first widely accepted design guide for V/STOL handling qualities (NASA TN D-331) and played the lead role in establishing a revised set of handling qualities criteria for military V/STOL aircraft for NATO (AGARD Report 577).

Significance

Using, to a large extent, the Ames V/STOL research information, MIL-F-83300 (V/STOL Flying Qualities Specification) was formulated to guide the design of military V/STOL

aircraft. In addition, application of Ames research has been reflected in the development of the AV-8B V/STOL Marine fighter and in the design of the XV-22 Osprey.

36. COOPER-HARPER RATING OF AIRCRAFT HANDLING QUALITIES

Description

The use of pilot rating in the evaluation of aircraft handling qualities was developed by G. E. Cooper of Ames and R. P. Harper, Jr., of Cornell Aeronautical Lab. It is a system of pilot ratings to describe aircraft handling qualities on a scale of 1 to 10. The rating scale describes aircraft characteristics through a pilot decision process and then assigns a numerical rating.

Significance

The Cooper-Harper Rating Scale standardized the system for evaluating aircraft handling qualities. It has become the standard for government as well as industry, both domestic and international.

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